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TRACKING OF KEY PERFORMANCE INDICATORS BY USING CONTROL CHARTS: CASE OF OEE STABILIZATION

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Abstract: *The purpose of this paper is to introduce the importance of putting Key Performance Indicators (KPI) into the holistic view of Continuous improvement methodology in modern manufacturing enterprises. The research was based on the continuous tracking of the OEE (Overall Equipment Effectiveness) indicator using the common tool of Lean approach – control charts. The simulation has consisted of two different types of control charts. Adopted conclusion expresses that fluctuation of OEE, and functioning of the fictive company itself, are susceptible to a positive influence of Lean management models. This study could be valuable, both for the academic and practical purpose, due to its structure which contains the practical method for measuring and continuous improvement of the production process, as well as the obtained business result itself.*

Keywords*: KPI, continuous improvement, lean manufacturing, OEE, control charts, simulation*

1. INTRODUCTION

In the modern business environment, there is the essential need to be constantly aware of extremely fluctuated market trends. After the commonly followed Western approach in business philosophy, today's importance of cost reduction principle caused the huge percentage of successful enterprises that base their business processes on Japanese Lean manufacturing model. Furthermore, the lean approach doesn't only mean the lower costs and money saving, but also the focus on involving all process participants in the venture of developing every single part of it.

Sources of knowledge which were being used during the research were the academic database of scientific papers (Science Direct, JSTOR, etc.). These sources were combined with the several case studies that were the basis for executed simulation. Using this kind of method, it has been tried to present how the appropriately established process of tracking and "attacking" the deviations, could lead to their reduction and bringing the business parameters into the zone of conformity.

The rest of the paper is organized as follow: Section 2 introduces the concept of KPIs and their definition and purpose. Section 3 describes how previously mentioned indicators could be involved in arranged system of continuous improvement, where management could derive the real meaning conclusions from indicators´ quantitative structure. After the section 4, which is related to the concept of control charts, section 5 is written to explain OEE indicator, as well as the simulation process carried out by using both mentioned tools. Section 6 concludes the paper with the review of the presented study and future research intentions.

2. KPIs – DEFINITION AND PURPOSE

In spite of growing importance of controlling and monitoring different business activities and results, putting performance measurement in place has always been a daunting task. Reasons such as the lack of incentives and top management support, as well as an organizational culture unfavourable to performance measurement, often make the development of performance measurement tool complicated and very challenging for ordinary businesses (Lindberg et al., 2015).

Cyclic management systems provide the basic concept, on which performance measurement system is based. This system is carried out by monitoring performance indicators, whose values indicate the results of certain management actions. Performance measures are system parameters or the method for quantitatively defining the process to be considered following the procedures of measurement and evaluation of performance. The main advantage achieved by the application of this kind of business approach is the possibility to provide information on potential quality improvements of company's performance.

In today's world economy, KPIs are an important tool to manage companies. In the first place, KPIs are used to divide important from unimportant information, simplify complex subject matters and create transparency. KPIs represent a set of measures focusing on those aspects of organizational performances that are the most critical for the current and future success of the organization (Parmenter, 2007).

In almost all modern business, we can always identify existence of time gap between the planning and execution. Because of this reason, different, unexpected events often occur during the execution. Consequently, there is always a gap between what was planned and what is actually done. In accordance with this problem, all of modern, competitive companies and their members need to make continuous efforts (or adaptations) to close the gap.

Performance metrics or KPIs offer the overall visibility of all company's processes and help to assess the accuracy of all plans (e.g. forecast accuracy), and the execution performance (e.g. actual sales versus forecast plan). KPIs reveal the gap between plan and execution and offer opportunities to identify, analyse and correct potential problems. Therefore, carefully selected KPIs precisely show where to take action in order to improve performance. KPIs help an organization to define and measure progress towards selected goals. If an organization has defined its goals, then it is more important for them to measure the progress of those goals (Jevgeni & Eduard & Roman, 2015).

Based on extensive analysis and discussions with over 1,500 participants in KPI workshops, covering most organization types in the public and private sectors, some of the basic KPI characteristics were defined. As examples, it can be highlighted that they are nonfinancial measures, which are frequently measured, and also make a significant impact on all company's processes (Parmenter, 2007).

One of the crucial tasks that refer to KPIs is a challenge of choosing number of KPIs that will be defined and monitored for a particular company. Unlike a general perception that more is better, in area of performance measurement "less is better". It is recommended to companies to start with a small number of KPIs which are absolutely necessary to monitor the multilevel processes (*plan, source, make, and deliver*) which they can successfully manage and operate. Another step that would undoubtedly make better review and understanding of KPIs by companies can also be hierarchical organization of those selected KPIs.

3. IMPLEMENTATION OF KPIs IN CONTINUOUS IMPROVEMENT PROCESS

If KPIs are mentioned as one of the crucial tools for process measuring, it is necessary to put them into the larger frame, where the results of the feedback would be significantly more valuable. The main purpose of this article is to introduce and explain the key role of combining mathematics with analysing processes, presented through KPIs, and continuous improvement way of thinking, which allows managers to understand processes and draw essential observations from quantitative data. Process improvement is the continuous methodology with aim, not only to eliminate deviations and non-value added activities, but also to fill in the performance gaps and level all kinds of activities and resources inside the production system (Sutari, 2015).

Approach to Continuous Improvement (CI), as the part of famous Japanese business philosophy, has spawned many various tools which are nowadays the foundations of modern industry world. As initial argument, unavoidable prerequisite for full implementation of CI process is the establishment of self-learning factory. As the concept, it stands for action-oriented approach in which employees (especially shop floor operators which are specialists for line or process stage they are responsible for) are encouraged in development of their own competencies in order to achieve improvements in production methods, reduction of all excessiveness and establishment of Lean production (Cachay & Abele, 2012). Therefore, only fundamental and multi-level system approach, where every single participant, in each company activity, has to leave his mark and impact along the way to some improvement, means that future prosperity lies on the reliable source – developed people. Essential importance of involvement of employees from every company department, and with different professions, will be further explained through particular case.

In theoretic concept of Lean manufacturing, there is present a huge pile of defined tools. Whether we are speaking of quality improvement tools like *Six Sigma* and *Poka-Yoke*, or methods related to time savings like *SMED* (Single Minute Exchange of Dies) or other scheduling methods like bottleneck analysis, all of them have the same unified goal – optimal process (Sundar, Balaji & Kumar, 2014). Even if it is clear that the word "optimum" is just a true north, commitment of every single participant in achieving it, is the promising way for company development. On the other side, repetitive return to the significance of the human role in case of this kind of production is necessity. Success of every senior Lean factory relies on the dedication and perceptions of their workers, no matter if they are called white or blue-collar. Due to that, suggestions, opinions and ideas of people who are in tight, everyday contact with process itself, are invaluable assets for managers and other decision makers.

All previously presented systematics naturally strive to be composited in some type of process entirety, which, according to the rule of closed circle, need to have iteratively and cyclically type of flow. Similar to the Deming´s PDCA (*Plan-Do-Check-Act*) approach, some theoreticians define DMAIC (*Define, Measure, Analyse, Improve and Control*) model, which is tightly related to Six-Sigma quality concept. According to Gejdoš (2015), DMAIC is "*extended model which refers to a data-driven improvement cycle used for improving, optimizing and stabilizing business processes and designs"*. According to both previously mentioned models, it is clearly notable that every sustainable improvement of any performance or process, first need to be decomposed to the exact points which then have to be evaluated, and then every part should be analysed as independent process with own specific characteristics and deviations. In order to minutely present and explain the whole, or some part of the process, there are several commonly used methods. One of the most frequently used is VSM (*Value Stream Mapping*), which relies on wide set of symbols and rules used for their networking (Rohani & Zahraee, 2015). In this way, every deviation would be entirely understandable and therefore attacked straight to the root cause. This kind of approach is one of the basic elements of the Lean production.

After the activities with purpose to define the nature of deviation, and evaluation of its influence on the holistic system picture after that, measuring is the phase which is mostly connected with some kind of calculations. Due to that, crucial point of this task is to segregate the appropriate method or model, which would express the most accurate current state. The most commonly used tool for this purpose, and one way to carry out the monitoring of the production process appropriately, is a control chart. How different types of control charts could be used to monitor different aspects of the production process, will be treated in the following section.

4. DEFINITION AND IMPORTANCE OF CONTROL CHART TOOL

According to the theory, control chart is significantly important tool stem from the wider concept of Statistical process control (SPC). SPC itself is a part of the comprehensive concept of Statistic Quality control (SQC), and its main purpose is analysing and inspecting if the randomly chosen outputs from particular process are within a predetermined range (Reid & Sanders, 2005). Based on the previous phase, management can evaluate stability and performance of the measured process.

Control charts are forms used to gather and describe values, statistical quantities, or production outputs for comparison, with previously established control limits. Initially, control charts are just graphical representation of measured results. Moreover, if the pile of collected observations is recorded over the long period, characteristics and behaviour of the process begin to be recognizable. These kinds of charts are the most frequently used tool in the statistical regulation of processes. Besides the fact that their ability to make impact on process quality, they are considered as a valuable tool for distinguishing random from systematic deviation causes. Due to significantly larger consequences after the special kind of reasons, and their practice to change the attributes of a process, they would be their most important object for measuring. Functioning of the chart systematic is based on samples taken from the process, which is usually taken on the fixed time interspace (Gejdoš, 2015).

The main aim of control charts is to be used in processes of monitoring and performance control. From the moment when deviation appeared, corrective actions are a must, to achieve a better mean value of the process, or to reduce variability of indicators. Visually, chart is presented as a histogram on which, the horizontal axis contains the terms when samplings were noticed, differently from the vertical axis which represents calculated values of the appropriate variables. Also, one of the greatest advantages of control charts is the easiness of use, even to the employees without advanced knowledge and skills in statistics and business analysis (Humble, 1998). Concreteness, time saving, and width of use, make this tool powerful for Continuous improvement methodology in every company.

5. TYPES OF CONTROL CHARTS

Considering dispersion of process variability as a base for analysing reliability of functioning, Range charts (R-charts) are used to secure the reduction of oscillations to the defined scope. For appropriate monitoring and process tracking, it is essential to establish upper and lower control limits, which could signal and separate special from the common deviation causes. Keeping indicator values within the defined scope will lead company to the crucial business stability. As an illustration, situation when there is at least one measured range outside the upper control limit, or there is specific upward trend of indicator within the control limits, process variability then has increasing trend. The fundament of continuous improvement methodology lies into the constant and iterative reduction of the variance.

As the main characteristic of R chart, difference between the maximum and minimum value of the measures in each period, should be calculated and divided to the number of observations. Consequently, the aim of every company is to stabilize each part of the process, and that stabilization is expressed through narrower interval of limits. Only when the company reaches the moment when process flow is stable enough and stated between the limits, it is suitable for them to apply another type of control chart.

The second type used during analysis is based on the mean of the gathered data. Therefore, theoretical titles for this kind of charts are “mean” or “X-bar” charts. Initial step of developing this methodology is based on calculating mean value of all measured observations. Then, for the purpose of accessing to a holistic view of organization process, average value is drawn from all individual mean values related to different moments in time (1).

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \cdots + \bar{x}_N}{N} \tag{1}$$

Similar to the R-charts, it is important step to set both limits (2) as a border in which, process variables must be integrated. In this type of chart, they are calculated in the following way:

$$\begin{aligned} \text{Upper control limit (UCL)} &= \bar{\bar{x}} + z\delta_{\bar{x}} \\ \text{Lower control limit (LCL)} &= \bar{\bar{x}} - z\delta_{\bar{x}} \end{aligned} \tag{2}$$

If symbol *z* is representing standard normal variable, which could lead to the specific level of certainty (2 for 95.44% confidence, 3 for 99.74%), variable δ stands for standard deviation of the distribution of sample means. Otherwise, usually practical way of calculating limits is based on multiplying $\bar{\bar{x}}$ with 0.9 or 1.1, that expresses increasing or reducing it by 10%.

It is crucial to emphasize that this type of chart should be used only when the fluctuations of the process variables are within the defined limits. This trait derives from the nature of mean method, which is quite unreliable in cases of often oscillations.

6. CASE OF OEE INDICATOR

Overall Equipment Effectiveness (OEE) represents a metric that is used to identify the percentage of planned production time that company exploits during the shifts. OEE score which is equal to 100% is considered as the true north state with manufacturing only good parts, as fast as possible, with no time losses. Three essential factors that constitutes OEE indicator are: Availability, Performance, and Quality. Each of them expresses different view on the types of deviations, which can be solved in order to close gaps and improve process (Puvanasvaran, Mei & Alagendran, 2013).

Availability as a parameter of OEE indicator refers to the percentage number that presents time availability of machine when there is production need for it. Difference in time between total production time and time shown by this parameter, is caused by breakdowns, setups and adjustments. Calculation (4) is given in following:

$$\text{Availability} = \frac{\text{Actual Production Time}}{\text{Planned Production Time}} \tag{4}$$

Performance efficiency (5), as sub-indicator, is used to express decreases of availability time by different causes of small disruptions (cleaning, checking, and jam) and reduced production speed (equipment wear, operator inefficiency). It takes in consideration actual and ideal run rate in order to show real equipment efficiency.

$$\text{Performance} = \frac{\text{Current Run Rate}}{\text{Ideal Run Rate}} \tag{5}$$

The quality rate (6) defines the accuracy of the process. It is used to show, how many of total production pieces, are in accordance with quality standards and principles. It is extremely important to reduce scrap and inappropriate parts by setting continuous improvement tools (e.g. Poka-Yoke). These results will have crucial impact, first on quality parameter, and the whole OEE indicator, too.

$$\text{Quality} = \frac{\text{Good Pieces}}{\text{Total Pieces}} \quad (6)$$

Combining these three previously mentioned variables, OEE indicator (7) would be the result of the following calculation:

$$OEE = \text{Availability} * \text{Performance} * \text{Quality} \quad (7)$$

For the purpose of this analysis, example of the fictive, manufacturing-oriented company is used to accurately represent importance and expediency of OEE implementation and tracking. Period that has been considered for making analysis and conclusions derived in this paper, is defined as one-year monthly based period.

Elements of production that were involved in the calculation include shift length, breaks, downtime, ideal cycle time, total parts and scraped parts. Combining these several variables, it is aimed to present how appropriate implementation and usage of control charts, will provide company with stability and improvement impacts on all its processes.

In the following table will be presented the calculation of OEE for one-month period:

Table 1: Input data for OEE calculation

Item	Data
Shift Length	8 hours
Breaks	1 hours
Down Time	1.25 hours
Ideal Cycle Time	12 seconds
Total Count	1580 pc
Reject Count	110 pc

According to the inputs in Table 1, and presented formulas (4,5,6 and 7) for individual indicators, achieved results are presented below in Table 2:

Table 2: OEE calculation

Item	Data
Availability	82.14%
Performance	91.59%
Quality	93.03%
OEE	**69.98%**

As the conclusion of the highlighted example, it could be noticed that only one parameter below the target level could cut down the holistic score regarding OEE. In this case, huge influence is observed by the variable availability score, which is caused by increased participation of breakdown time in total production time. Therefore, the first advice that could be given to the company is to work continuously on productivity and time usage improvement.

By application of the same method as above, calculation lead to the overall OEE results for all further months of the particular year. For the purpose of this paper, two types of control charts were used (X-bar chart and R-chart) within the simulation algorithm to properly analyse impacts of different production elements on the value of OEE indicator and process itself.

Simulation conclusions would be analysed in two different ways. First one is presented on the R-chart and refers to the diversity of different samples that were noticed during one month. As it was highlighted before, the main significance of the R-chart is to show if differences in measurement result in each period are within the set target scope.

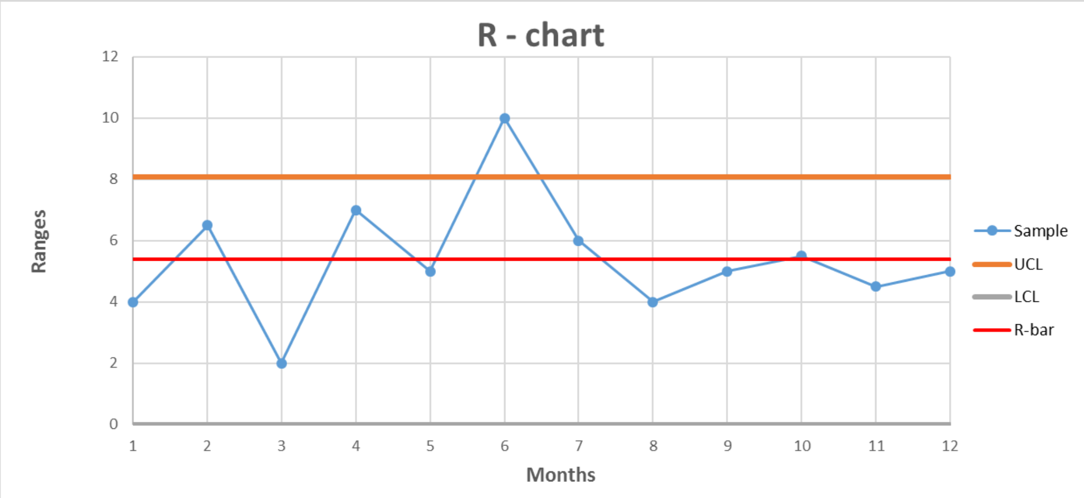

Figure 1: R - chart on example of OEE indicator

The graph above shows importance of accurate control and adequate influence on production process according to the OEE oscillations. As it is noticed in the first six months, there are huge variations in gathered data values between consecutive months. In the sixth month, value of the indicator is rocketed high and above the set upper limit. That signals that the production process of the company faced unusual special cause, which must lead to the investigation, analysis, and corrective actions.

It is important to emphasize that every company department and all employees of all levels of hierarchy, must be completely involved in the process of monitoring and stabilization of this essential process traits. For the reduction of the OEE within the framework defined by the control limits, all of its parameters must be thoroughly analysed. Seeing that the OEE is a too complex and comprehensive variable, it must be "attacked" from the several different aspects. For this purpose, suggested way for improving the whole results is to track and constantly improve the individual values of availability, performance, and quality of the "tools" to make a bigger impact on the future stability of the compound OEE variable.

As the responsible department for working on the boosting the performance sub-indicator, could be mentioned the production department itself, which has to secure appropriate ergonomic conditions, in order to reduce the ideal cycle time per part/product. In this task, they must have support from the company's technicians.

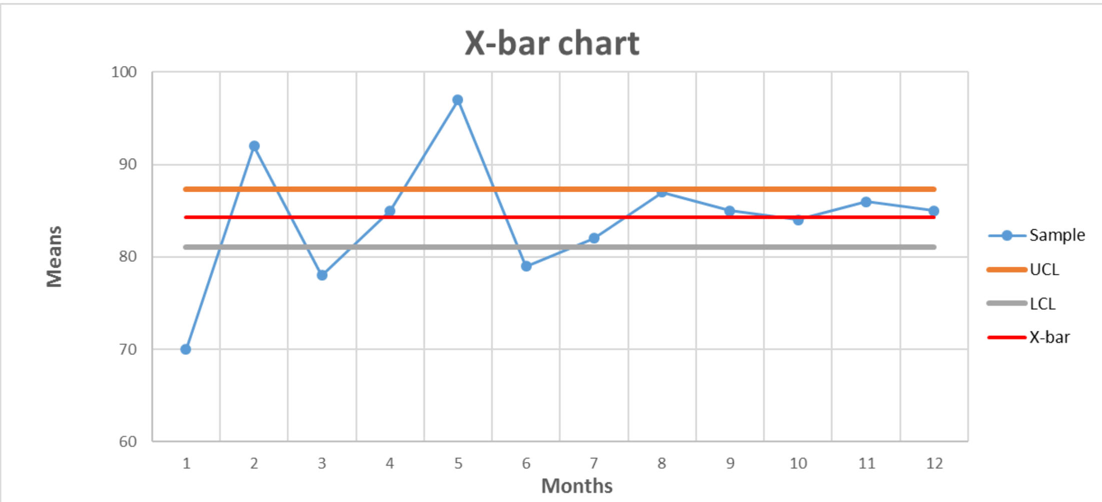

Figure 2: X-bar chart

Quality sub-indicator refers to the reducing of scrap and inappropriate production parts, as well as the early revealing of the damaged parts delivered from the suppliers. With the previous, quality department fulfils all necessary standards for deviations prevention in order to secure smooth process flow.

Availability is connected with organizational harmoniousness and it is responsibility of every company's department to work on it. With more minutes or seconds for value added activities, company has a good base to be stronger competitive in the market race.

As the previously highlighted measures and required approach were implemented, variations of observed variable are reducing. For every company, this is a precondition for a timely application of X-bar chart. It distinctly presents variations between monthly measured averages of taken samples, and represent the basis for stability of variable first, and then of the whole process, too.

In the graph above, impact of corrective actions by different company's departments could be clearly identified. In first half of the year, value of OEE indicator is almost always outside defined limits, and during this period, application of X-bar chart is worthless. When impacts on process are made, X-bar chart becomes a powerful tool, which, if it is used properly, provides crucial process consistency and gives significant benefits to the whole company's business.

Finally, it is important to emphasize that stable and precisely defined process provides significant certainty to all departments, referring to every process performance, and consequently, to all tasks that they should accomplish.

7. CONCLUSION

As has been noted, the present research aimed at investigating and emphasizing of essential impact that continuous improvement tools have on the frame of production process performances. In addition, it is presented how crucial is the appropriate usage of the key performance indicators in order to extract maximum utilizable information from its rigidly quantitative essence. For this purpose, simulation was conducted over the data of the fictive manufacturing company with combined methodology based on X-bar and R control charts.

The results of this study could be used in further research, both for operations managers in companies and scholars, due to its wide applicability in field of industrial engineering. Besides the limitation of the study caused by its basing on the simulation and data of the fictive company, all implemented tools, management advice and conclusions are derived from the analyses of the many real company case studies. Taking into account common causes of inappropriate asset utilization and all other deviations, this paper was attempted to explain methods, which could be easily used even by the non-engineers.

Further research in this field of study should focus deeper on developing and combining new types of control charts, as well as on possibilities for its application in other areas of production and operations management. Consequently, many other production losses could be deeply investigated and reduced, taking into account the reliable support provided by statistical methods and models.

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A NOVEL ALGORITHM FOR COMBINATORIAL PROBLEM IN MANUFACTURING CELL FORMATION

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Abstract: *In this paper we consider machine and part family grouping for cell formation. Manufacturing cell formation is the first and foremost issue in designing cellular manufacturing systems. The primary objective of this step is to cluster machines into machine cells and parts into part families so that the minimum of intercell trips will be achieved. For this purpose, the Generalized Constructive Algorithm is applied for solving the combinatorial optimization problem in manufacturing cell formation. The objective is to maximize the sum of similarity coefficients between machine/part pairs. This formulation is suitable for effective narrowing of the feasible solution set. A parameter determining the precision of the search of the feasible solution set is introduced. The Generalized Constructive Algorithm constructs a solution population from the feasible set. The initialization phase of the Generalized Constructive Algorithm utilizes the advantages provided by the definition of the objective function. Experimental evaluation confirms the advantages of the proposed approach regarding known results.*

Keywords: *group technology, similarity measure, constructive algorithm, cluster analysis*

1. INTRODUCTION

Group technology is an approach that identifies attributes of the population suitable for grouping its members into groups, or families (Ilić 2015). Cellular manufacturing is an application of group technology in manufacturing in which all, or a portion, of a firm's manufacturing system has been converted into cells. The layout of a facility contributes significantly to the speed of product throughput achieved by the facility. Cell formation can be defined as grouping the parts into part families, and the machines into machine cells, and then assigning the part families into corresponding machine cells. Thus, the Cell Formation Problem (CFP) can be defined as a problem of grouping machines into groups that minimizes the number of parts to be processed on machines from different groups. CFP is known as an NP-hard problem, due to its computational complexity.

This paper proposes a method based on the definition of the problem in Ilić (2014), where the optimization procedure is carried out by applying the Generalized Constructive Algorithm (GCA), shown in (Danilović and Ilić 2013, 2016). In Ilić (2014), the proposed objective function takes into account only the neighbor elements in the permutation of machines and parts. Thus defined objective function opens up great possibilities for the implementation of the optimization process. Limiting the mutual influence only to neighbor elements in the permutation allows defining the rules that significantly reduce the feasible solution set. These rules are formulated through five lemmas, presented in the Section 4.

The research, presented in this paper, is focused to the improvement of the procedure of determining the optimal arrangement of machines and parts, assuming that the cell formation is conducted in the same manner as in Ilić (2014). The suitability of the formulation of the problem in Ilić (2014) allows that the initial arrangement, *i.e.* the first phase of GCA, is applied after narrowing the feasible solution set (Danilović and Ilić 2016a). This significantly increases the efficiency of the process, what's more, in that way specific instances can be solved using exact procedures.

The paper is organized as follows. After the introduction, Section 2 presents related works. The problem formulation is given in Section 3. In Section 4 five lemmas are proven which enable narrowing of the feasible solution set. The hypothesis that defines the precision of the search of the feasible solution set is stated. The proposed procedure is presented in Section 5, while the comparison of the proposed approach with the program PFAST is given in Section 6. Concluding remarks and directions of future research are given at the end of the paper.

2. LITERATURE REVIEW

Due to its importance in the design of cellular manufacturing systems, the CFP has been given considerable attention in literature. There have been many different approaches and practical researches conducted on the CFP (Yin et al. 2005; Hachicha et al. 2008; Pattanaik and Sharma 2009). A comprehensive review of CFP approaches is given in Singh (1993). Extended reviews of the various approaches are available in the literature (Reisman et al. 1997; Selim et al. 1998; Papaioannou and Wilson 2010).

Most CFP methods in the literature assume that parts have only a unique process routing. Also, in most of the studies, cell formation is performed assuming all machines to be reliable (Jabal-Ameli and Akart 2008). Machine-component Group Analysis (MCGA) is based on Production Flow Analysis (Burbidge 1977). In MCGA-based methods, machine-component groups are formed by permuting rows and columns of the machine-component chart in the form of a zero-one matrix. Rank Order Clustering (ROC) (King 1980) is a simple algorithm used to form a machine-part group. The algorithm is based on the sorting rows and columns of the machine-part incidence matrix. A Direct Clustering Algorithm (Chan and Milner 1982) sorts the total number of 1's in each row and column in increasing and decreasing order to form the clusters. MODROC algorithm, developed by Chandrasekharan and Rajagopalan (1986) offers improvements over ROC.

Similarity coefficient-based approaches are distinguished from the other approaches by their flexibility in incorporating various types of manufacturing data into the CFP, and suitability for development software tools. A number of similarity coefficients have been analyzed and proposed in literature (Yin and Yasuda, 2005; Yin and Yasuda, 2006). Among various similarity coefficients, Jaccard similarity coefficient was the most used in literature and the most stable similarity coefficient (Yin and Yasuda, 2005). Oliveira, et al. (2008) reviewed 8 different similarity coefficients. Four of them are Jaccardian and the rest are non-Jaccardian coefficients. They concluded that the one similarity coefficient can be chosen over others according to the preference of the cell formation. For example, if the fewest intercell flows is the main focus, McAuley's Jaccardian coefficient should be used. Also, McAuley's Jaccardian coefficient is preferred when the strength of clustering is the key factor of judging the quality of a solution. Similarity coefficient-based approaches have been widely used since McAuley (1972) for the first time combining the Jaccard similarity coefficient with the Single Linkage Cluster analysis, which was resulted in construction of a tree called a dendrogram. This was followed by development of other similarity coefficient-based approaches. Recently, the Cluster Analysis (CA) was discussed and attention was drawn to the main decisional step of CA based on similarity coefficient methods (Manzini, et al., 2010). One group of researchers used similarity coefficient-based method for generating a good initial solution for CFP (Wu, et al., 2009; Chung, et al., 2011). An e-Learning tool considering similarity measures is presented by Ilić (2014).

3. PROBLEM FORMULATION

Similarity coefficient represents a measure of similarity between machines/parts which is used to group them together. The value of the similarity coefficient usually ranges from 0 to 1. If this value is equal to 0, there is no similarity between two machines/parts. Conversely, as this value is closer to 1, the two machines/parts are more similar.

The similarity coefficient between machine *i* and machine *j* is defined as the ratio of the number of parts visiting both machines and the number of parts visiting one of the two machines as follows:

$$s_{ij}^{M} = \frac{a_{ij}^{P}}{a_{ij}^{P} + b_{ij}^{P} + c_{ij}^{P}}; \quad 0 \le s_{ij}^{M} \le 1 \tag{1}$$

where a_{ij}^{P} is the number of parts that visit both machines *i* and *j*; b_{ij}^{P} is the number of parts that visit machine *i* but not *j*; c_{ij}^{P} is the number of parts that visit machine *j* but not *i*.

The similarity coefficient between part *k* and part *l* is:

$$s_{kl}^{P} = \frac{a_{kl}^{M}}{a_{kl}^{M} + b_{kl}^{M} + c_{kl}^{M}}; \quad 0 \le s_{kl}^{P} \le 1 \tag{2}$$

where a_{kl}^M is the number of machines used by both parts *k* and *l*; b_{kl}^M is the number of machines used by part *k* but not *l*; c_{kl}^M is the number of machines used by part *l* but not *k*.
The optimisation procedure for machines finds the permutation $(\pi_1,...,\pi_m)$ of machine labels (1,..,*m*), which maximizes value $\sum_{i=1}^{m-1} s_{\pi_i \pi_{i+1}}^M$.

The optimisation procedure for parts finds the permutation $(\Pi_1,...,\Pi_n)$ of part labels (1,..,*n*), which maximizes value $\sum_{k=1}^{n-1} s_{\Pi_k \Pi_{k+1}}^P$.

A deterministic combinatorial optimization problem may be formulated as a quadruple (*I*, *F*, *C*, *g*), where:

- *I* is a given instance of the combinatorial optimisation problem;
- *F*(*I*) is the finite set of feasible solutions for a given instance *I*;
- *C*(*x*), $x \in F(I)$, denotes a real-valued objective function, which is a measure of the feasible solution *x*;
- *g* is the goal function, and is usually “min” or “max”.

The goal is then to find, for a given instance *I*, an *optimal solution*, that is, a feasible solution *x* with:
$C(x) = g\{C(x') \mid x' \in F(I)\}$

In the significant number of combinatorial optimisation problems (scheduling problems, routing problems, assignment problems) $I = O^n = \{o_1,...,o_n\}$ is a set of *n* objects, each having defined properties and $F(O^n)$ can be formalized by different sequences of these objects. The selection of objects and the order of objects in a sequence determine the corresponding *C* value. Let $PR^n = \{pr_1,...,pr_n\}$ denote a set of object properties (pr_i are properties of object o_i). The set of given objects O^n can be defined formally, without loss of generality, as a bijection from the set $S^n=\{1, 2,..., n\}$ to O^n. In that way, *I* can be represented by PR^n, and $F(O^n)$ can be represented by permutations π^n of S^n. Heuristics for solving these problems differ only by the manner in which they form the permutations and the criteria for the selection of desirable permutations.

Constructive search techniques work by constructing a solution step by step, evaluating that solution for feasibility and objective function. Insertion based constructive heuristics typically have common structures, comprising the *initialization* phase and the loop in the *insertion* phase. In the initialization phase, the selection function $f_1(PR^n)$ determines an integer e_1 from S^n, that will be included into the solution *x*. The insertion phase has *n*-1 iterations, such that, at the beginning of the *k*-th iteration, S^n is partitioned into two subsets: $PRT^2(S^n) = (PRT_1^k(S^n), PRT_2^{n-k}(S^n)) = (A_1^k, A_2^{n-k})$.

At each iteration *k* of the insertion phase, two types of selections are performed: a selection $f_2(PR^n, k, A_2^{n-k})$ of the integer e_{k+1} from A_2^{n-k} to be removed from A_2^{n-k} and the selection $f_3(PR^n, k, e_{k+1}, \rho^k[A_1^k])$ of the position *l* in $\rho^k[A_1^k]$ where e_{k+1} will be inserted. Performed insertion uniquely determines the arrangement of integers in $\rho^{k+1}[A_1^{k+1}]$.

GCA may be defined as a function $x \leftarrow CA(PR^n, F, C, g, f_1, f_2, f_3, ARG)$, where *ARG* = {$\boldsymbol{arg_1}$,...,$\boldsymbol{arg_7}$} is the set of seven optional arguments. In this research, only $\boldsymbol{arg_4}$ having value R_1 is considered, *i.e.* algorithm tracks simultaneously all partial permutations that result in current optimal value of the objective function.

4. NARROWING THE FEASIBLE SET

The proposed similarity coefficient objective function takes into account only the neighbor elements in the permutation of machines and parts. Limiting the mutual influence only on neighbor elements in the permutation allows defining the rules that significantly reduce the feasible solution set. These rules are formulated through five lemmas, stated in this Section. As there is a direct analogy between the optimization of machine arrangement and arrangement of parts, the remainder of this paper considers only the optimization for machines.

Lemma 1 (Symmetric solution): Each optimal solution has its symmetric solution that is also optimal; symmetric solution is obtained by reversing the original permutation.

The proof of this Lemma is obvious. Since the value of the objective function is obtained summing similarity coefficients of the neighbor elements in the permutation, same value is obtained if the summands are reversed.

Lemma 2 (Complete matching): If $s_{ij}^{M} = 1$, the position of machine *i* in the optimal permutation is next to the position of machine *j*.

Lemma 3 (Transition): If $s_{ij}^{M} = 1$ and $s_{jk}^{M} = 1$, then $s_{ik}^{M} = 1$.

Lemma 4 (Group matching): If a subset of machines has mutual similarity coefficient equal to 1, every permutation of these machines within the entire permutation results in the same value of the objective function.

The proof of these Lemmas can be derived as follows: The value of the objective function is obtained by summing only the similarity coefficients of neighboring machines in the permutation. Suppose, without loss of generality, that the machines *i* and *j* have a similarity coefficient equal to 1, and that all other coefficients are less than one. Suppose that, in the first case, the optimal partial sequence of machines is *k i j l,* and in the second case *k i q j l.* The similarity coefficient for machines *i* and *q* is less or equal than the similarity coefficient for machines *i* and *k*, otherwise *k i j l* is not the optimal permutation. In the same way, the similarity coefficient for machines *j* and *q* is less or equal to the similarity coefficient for machines *j* and *l*. Thus, the summand, having value 1, is in the second case replaced with the summand with the value less than 1; the added summand in the second case is less or equal to the corresponding summand in the first case. This completes the proof of the Lemma 2. Accordingly, proofs of Lemma 3 and Lemma 4 are straightforward.

The conclusions of these Lemmas can be extended to the cases where the similarity coefficients are not equal to one.

Lemma 5 (Clustering): If the subset of machines has all of their mutual similarity coefficients greater than x, and if all the other similarity coefficients are less than x, in the optimal permutation all those machines belong to the same compact group. Mutual arrangement of machines within this group will match the permutation of the group that has the largest partial value of the objective function.

The proof of this Lemma is analogous to the previous proof.

It is clear that the obtained conclusions may define the procedures which significantly reduce the feasible solution set. While the first four lemmas imply exact reduction of the feasible set, Lemma 5 implies the possibilities for the near optimal reduction of the feasible set. Figure 1 presents an agglomerative cluster dendrogram representing similarity of machines A, B, C, D, E, F and G.

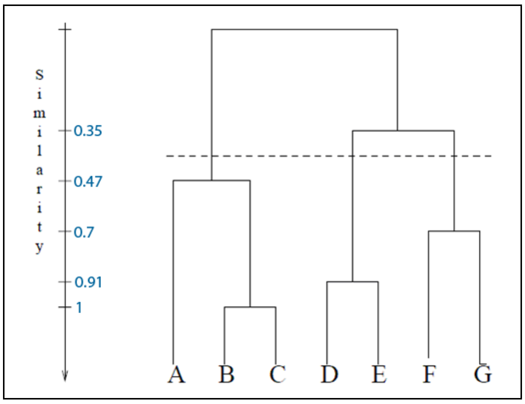

Figure 1: Agglomerative cluster dendrogram

According to Lemma 2, machines B and C, having similarity coefficient equal to 1, are always neighbors in optimal permutations. According to Lemma 5, if the precision parameter is 0.8, two clusters, {B,C} and {D,E} are constructed (D and E have the similarity coefficient 0.91 which is greater than 0.8). If the precision parameter is 0.5, three clusters, {A,B,C}, {D,E} and {F,G} can be constructed.

5. THE NOVEL ALGORITHM

The adopted objective functions and the pre-defined level of clustering are the ideal conditions to define the arrangement that provides the initial phase of the GCA. Since the GCA can simultaneously track multiple initial permutations, it can be formally defined as:

$$x \leftarrow CA(PR^n, F, C, g, f_1, f_2, f_3, \boldsymbol{arg}_4 = R_1). \tag{3}$$

This definition also allows a trivial application of parallel programming, because the individuals in the initial population can be treated completely independently of each other. The initial grouping and arrangement can be summarized through five steps:

Step 1. Each group of machines having all similarity coefficients equal to 1 are replaced with a single, arbitrarily selected machine from the group.
Step 2. Define the parameter $p \leq 1$.
Step 3. Apply the cluster algorithm so that the lowest similarity coefficient in each of the clusters is greater than or equal to *p*. Let y_q denote the lowest similarity coefficient in the *q*-th cluster (if the machine does not belong to any cluster, the corresponding value is equal to its largest similarity coefficient).
Step 4. Sort clusters according to non-increasing values of y_q.
Step 5. Determine the permutations of machines in each cluster that provide the greatest values of the objective function. Let z_q denote the optimal number of partial permutations within the *q*-th cluster. Any combination of the obtained optimal partial permutations determines an initial arrangement for the GCA. In the insertion phase of GCA, each cluster is treated as one element in the permutation. When the *k*-th iteration determines the permutation of length *k*, each cluster in the permutation is replaced with its elements.

Even before the experimental verification of the proposed approach, certain benefits are obvious. Although the proposed approach does not guarantee the optimal value of the objective function, it enables an efficient processing, due to an important fact: the number of steps of the algorithm is predefined with only two variables, *m* and *p*, so the user is informed in advance precisely what will be the consumption of CPU time. In this way, the user can adjust the search precision to the available computer time, *i.e*. to choose the greatest possible value for p.

6. EXPERIMENTAL RESULTS

The quality and efficiency of the proposed procedure are verified on the example, which is discussed in Ilić (2014), and Ilić and Cvetić (2014). In these researches, the results are compared with the results of Irani, *et al.* (2000), Irani and Huang (2005), and Irani (2012), obtained by the software package PFAST. Table 1 illustrates the process paths for 19 parts on 12 machines.

Table 1: Routing sheet

1	1	4	8	9			
2	1	4	7	4	8	7	
3	1	2	4	7	8	9	
4	1	4	7	9			
5	1	6	10	7	9		
6	6	10	7	8	9		
7	6	4	8	9			
8	3	5	2	6	4	8	9
9	3	5	6	4	8	9	
10	4	7	4	8			
11	6						
12	11	7	12				
13	11	12					
14	11	7	10				
15	1	7	11	10	11	12	

16	1	7	11	10	11	12	
17	11	7	12				
18	6	7	10				
19	12						

Based on the above routing sheet, similarity matrices for machines and parts are shown in Table 2 and Table 3 respectively. The diagonal elements are marked in grey, indicating the only elements that contribute to the value of the objective function. The bold marked elements of the matrix are the elements having the value above the stated threshold, which is 0.7 for both, machines and parts.

Table 2: Similarity coefficients for machines

	1	2	3	4	5	6	7	8	9	10	11	12
1		0.125	0	0.364	0	0.077	0.462	0.25	0.364	0.3	0.182	0.182
2			0.333	0.25	0.333	0.125	0.077	0.25	0.25	0	0	0
3				0.25	**1**	0.286	0	0.25	0.25	0	0	0
4					0.25	0.25	0.25	**0.78**	0.6	0	0	0
5						0.286	0	0.25	0.25	0	0	0
6							0.188	0.364	0.5	0.3	0	0
7								0.25	0.25	0.5	0.385	0.286
8									0.6	0.077	0	0
9										0.167	0	0
10											0.333	0.2
11												**0.71**
12												

Table 3: Similarity coefficients for parts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1																			
2	0.6																		
3	0.667	0.667																	
4	0.6	0.6	0.667																
5	0.286	0.286	0.375	0.5															
6	0.286	0.286	0.375	0.286	0.667														
7	0.6	0.333	0.429	0.333	0.286	0.5													
8	0.375	0.222	0.444	0.222	0.2	0.333	0.571												
9	0.429	0.25	0.333	0.25	0.222	0.375	0.667	0.857											
10	0.4	**0.75**	0.5	0.4	0.143	0.333	0.4	0.25	0.286										
11	0	0	0	0	0.2	0.2	0.25	0.143	0.167	0									
12	0	0.167	0.125	0.167	0.143	0.143	0	0	0	0.2	0								
13	0	0	0	0	0	0	0	0	0	0	0	0.667							
14	0	0.167	0.125	0.167	0.333	0.333	0	0	0	0.2	0	0.5	0.25						
15	0.125	0.286	0.222	0.286	0.429	0.25	0	0	0	0.143	0	0.6	0.4	0.6					
16	0.125	0.286	0.222	0.286	0.429	0.25	0	0	0	0.143	0	0.6	0.4	0.6	**1**				
17	0	0.167	0.125	0.167	0.143	0.143	0	0	0	0.2	0	**1**	0.667	0.5	0.6	0.6			
18	0	0.167	0.125	0.167	0.6	0.6	0.167	0.111	0.125	0.2	0.333	0.2	0	0.5	0.333	0.333	0.2		
19	0	0	0	0	0	0	0	0	0	0	0	0.333	0.5	0	0.2	0.2	0.333	0	

The values of the objective functions for these arrangements of machines and parts are 3.496 for machines and 8.632 for parts. For the stated tresholds of 0.7, three clusters are identified for machines and four clusters for parts. Clusters for machines are {3,5}, {4,8} and {11,12}, clusters for parts are {15,16}, {12,17}, {8,9} and {2,10}. These clusters narrow feasible sets: from 12! to 2!2!2!9! for machines, and from 19! to 2!2!2!2!15! for parts. Thus, total search can be applied to obtain solution for machines, while GCA should be applied to obtain results for parts. Total search for machines results in four (2 symmetric) optimal arrangements, having 5.87 as the value of the objective function. These arrangements are shown in Table 4.

Table 4: Optimal arrangements of machines

	1	2	3	4	5	6	7	8	9	10	11	12
1	12	11	10	7	1	4	8	9	6	3	5	2
2	2	3	5	6	9	8	4	1	7	10	11	12
3	12	11	10	7	1	4	8	9	6	5	3	2
4	2	5	3	6	9	8	4	1	7	10	11	12

Arrangement 4 is symmetric to arrangement 1, while arrangement 3 is symmetric to arrangement 2. When GCA is applied for parts, 16 (8 symmetric) optimal arrangements are obtained, with 11.418 as the value of the objective function. These arrangements are shown in Table 5.

Table 5: Optimal arrangements of parts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	11	8	9	7	1	3	4	2	10	6	5	18	14	15	16	12	17	13	19
2	11	8	9	7	1	4	3	2	10	6	5	18	14	15	16	12	17	13	19
3	11	8	9	7	1	3	4	2	10	6	5	18	14	16	15	12	17	13	19
4	11	8	9	7	1	4	3	2	10	6	5	18	14	16	15	12	17	13	19
5	11	8	9	7	1	3	4	2	10	6	5	18	14	15	16	17	12	13	19
6	11	8	9	7	1	4	3	2	10	6	5	18	14	15	16	17	12	13	19
7	11	8	9	7	1	3	4	2	10	6	5	18	14	16	15	17	12	13	19
8	11	8	9	7	1	4	3	2	10	6	5	18	14	16	15	17	12	13	19

The lower threshold implies reduced processing time with the possibility of worse objective function values. To investigate that, the threshold of 0.66 is stated for the optimization of the arrangement of parts. Five clusters are obtained: {14,15}, {16,17,18}, {2,3,4}, {5,6,7,8,9} and {10,11}. This grouping reduces the size of the feasible solution set from 19! to 2! 3! 3! 5! 2! 9!. It is interesting that despite the significant reduction in the feasible solution set, and significant savings in CPU time, GCA provides optimal results identical to the previous experiment, when the threshold was 0.7.

7. CONCLUDING REMARKS

This paper presents a procedure for arrangement of machines and parts in the process of cell formation. The objective is to determine the arrangements that maximize the objective function, proposed in Ilić (2014). It is shown that GCA is extremely suitable as an optimization heuristic because its initialization phase can utilize the advantages provided by such a defined objective function with some modifications in the cluster process. Specifically, applied definition of objective function allows simple clustering of machines and parts and the introduction of the precision parameter for the GCA search. Experimental results clearly show that such a defined GCA provides optimal results on the observed test instances with significant saving of the CPU time.

Future research should be directed towards the application of the obtained results when objective functions, extended from the definition in Ilić (2014), are applied. Namely, it is possible that a certain problem requires the involvement of the influence of non-adjacent elements in the permutation on the value of the objective function. However, also in these cases, the former results should be unavoidably used. Information obtained by using the objective function in Ilić (2014) is valuable for narrowing the feasible solution set for any objective function applied.

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APPLICATION OF MODERN CONTROL THEORY TO INVENTORY CONTROL IN PHARMACEUTICAL DISTRIBUTION COMPANY

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Abstract: *Modern Control Theory (MCT) is an interdisciplinary area, which combines different mathematical concepts and methods in order to produce body of applied mathematics. This paper presents MCT as efficient tool for inventory control in pharmaceutical distribution companies. Inventory system of the pharmaceutical distribution company, which is considered as an example in this paper, has continuously changing state of sales. States of inventories are registered at the ends of the defined time period. Considered time horizon is one year. Structure of inventory system is generally known and represents sales forecast per months. The system was modelled based on the feedback control systems methodology. During the model creation, all elements of a feedback loop (reference, system, sensor, comparator, and controller) are created. When one or more output variables of a system have to follow a certain reference over time, a controller manipulates the inputs to a system in goal of obtaining the desired effect on the output of the system. Inventory control problem, modelled in accordance with MCT concept, is developed in spreadsheet. Spreadsheet is used for creation of decision making model. The results obtained from the model are used for procurement planning for more than 50 products per country, for five countries from East-Central Europe in year 2016.*

Keywords*: control theory, feedback loop, inventory control, pharmaceutical company, decision making model, spreadsheet*

1. INTRODUCTION

Pharmaceutical is one of the most sensitive and major industry that deals with human life. Quality and security are the most important to maintain. Inventory management of the industry is a difficult job. A pharmaceutical companies handle 500-600 types of products that includes huge amount of raw materials movement, packaging, secondary packaging of the finished products and delivering to the customers. Planning and scheduling in the pharmaceutical companies is a critical activity.

The primary distribution management goal is to maintain a steady supply of pharmaceuticals and supplies to facilities where they are needed, while costs of distribution should be the lowest. Distribution costs include costs related to storage, transport, customs and analysis etc. Designing a system for storing and distributing pharmaceuticals and medical supplies is complex and important.

Effective pharmaceutical distribution relies on good system design and good management. A well designed and well managed distribution system should (Managing distribution, 2012):

- Maintain a constant supply of medicines;
- Keep medicines in good condition throughout the distribution process;
- Minimize medicine losses caused by spoilage and expiry;
- Rationalize pharmaceutical storage points;
- Use available transport resources as efficiently as possible;
- Reduce theft and fraud;
- Provide information for forecasting medication needs;
- Incorporate a quality assurance program.

Centralized distribution is one option for pharmaceutical producer companies. Some countries procure and distribute medicines regionally, and some use commercial supply systems, which often exist in parallel with public systems. Collaboration between private and public systems may occur at any level. Private distribution companies can provide cost-effective alternatives for the storage and distribution of medicines, especially at the national and regional levels.

This paper presents simulation model, created to analyze the pharmaceutical distribution process and to determine ordering periods, in private pharmaceutical distribution company from Serbia. Model is aimed to help the pharmaceutical distribution company to determine the reorder point for products and to reduce wastage in time and money. Model is designed based on MCT concepts.

2. MODERN CONTROL THEORY

The modern control theory is a discipline dealing with formal foundations of the analysis and design of computer control and management systems. Its basic scope contains problems and methods of control algorithms design, where the control algorithms are understood as formal prescriptions (formulas, procedures, programs) for the determination of control decisions, which may be executed by technical devices able to the information processing and decision making. The problems and methods of the control theory are common for different executors of the control algorithms. The control theory deals with the foundations, methods and decision making algorithms needed for developing computer programs in such systems. The problems and methods of the control theory are common not only for different executors of the control algorithms but also, which is perhaps more important, for various applications. In the first period, the control theory has been developing mainly for the automatic control of technical processes and devices. This area of applications is still important and developing, and the development of the information technology has created new possibilities and on the other hand new problems. The full automatization of the control contains also the automatization of manipulation operations, the control of executing mechanisms, intelligent tools and robots which may be objects of the external control and should contain inner controlling devices and systems. Taking into account the needs connected with the control of various technical processes, with the management of projects and complex plants as well as with the control and management of computer systems has led to forming foundations of modern control science dealing in a uniform and systematic way with problems concerning the different applications mentioned here. The scope of this area significantly exceeds the framework of so called traditional (or classical) control theory. The needs and applications mentioned above determine also new directions and perspectives of the future development of the modern control theory (Bubnicki, 2002).

Summarizing the above remarks one can say that the control theory (or wider − control science) is a basic discipline for the automatic control and robotics and one of basic disciplines for the information technology and management. It provides the methods necessary to a rational design and effective use of computer tools in the decision support systems and in particular, in the largest class of such systems, namely in control and management systems (Bubnicki, 2002).

The process of designing a control system generally involves many steps. A typical scenario can be presented as follows (Antic et al. 2012):

- Study the system to be controlled and decide what types of sensors and actuators will be used and where they will be placed;
- Model the resulting system to be controlled;
- Simplify the model if necessary so that it is tractable;
- Analyze the resulting model and determine its properties;
- Decide on performance specifications;
- Decide on the type of controller to be used;
- Design a controller to meet the specs, if possible. if not, modify the specs or generalize the type of controller sought;
- Simulate the resulting controlled system, either on a computer or in a pilot plant;
- Repeat from the first step, if necessary;
- Choose hardware and software and implement the controller;
- Tune the controller on-line, if necessary.

Control systems are most often based on the principle of feedback, whereby the signal to be controlled is compared to a desired reference signal and the discrepancy used to compute corrective control action, (Doyle et al. *1990).* The most elementary feedback control system has three components (Figure 1):

- a system (the object to be controlled, no matter what it is, is always called the system or plant),
- a sensor to measure the output of the plant, and
- a controller to generate the plant's input.

External input of a system is called the reference. When one or more output variables of a system need to follow a certain reference over time, a controller manipulates the inputs to a system to obtain the desired effect on the output of the system. The usual objective of control theory is to calculate solutions for the proper corrective action from the controller that result in system stability, that is, the system will hold the set point and not oscillate around it. The concept of the feedback loop to control the dynamic behaviour of the system: this is negative feedback, because the sensed value by sensor is subtracted from the desired value to create the error signal, which is amplified by the controller (Doyle et al. 1990).

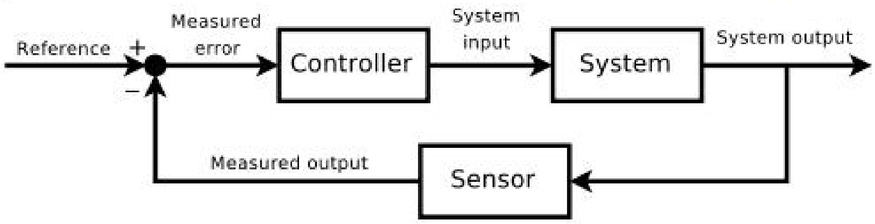

Figure 1: Concept of the feedback loop

Sensor can be define as device that converts a physical stimulus or input into a readable output, which today would preferably be electronic, but which can also be communicated via other means, such as visual and acoustic. As perhaps the simplest example, consider the sensor on keyboard switch actuator - which provides a signal when the associated key is pressed. The role of a sensor in a simple automation system is depicted in Figure 2. The detection and measurement of some physical effect provides information to the control system regarding a related property of the system under control, which we are interested in regulating to within some "set point" range. The controller outputs a command to an actuator (a valve, for example) to correct for measured deviations from the set point, and the control loop is thereby closed. Because of the simplicity of example in Figure 2 control system, it represents a fair number of practical control systems. In especially simple systems, a distinct controller may not be immediately evident (for example, thermostat), (Zook et al. 2008).

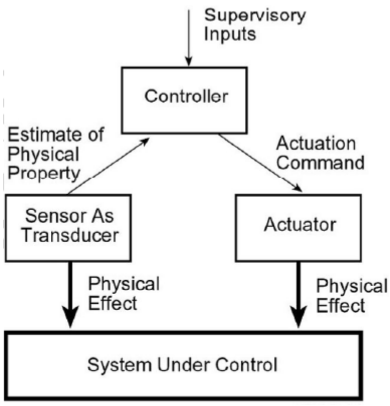

Figure 2: Example of a simple control system

A dynamical system is a system whose behaviour changes over time, often in response to external stimulation or forcing. The term feedback refers to a situation in which two or more dynamical systems are connected together such that each system influences the other and their dynamics are thus strongly coupled. Simple causal reasoning about a feedback system is difficult because the first system influences the second and the second system influences the first, leading to a circular argument. This makes reasoning based on cause and effect tricky, and it is necessary to analyze whole systems. A consequence of this is that the behaviour of feedback systems is often counter intuitive, and it is therefore necessary to resort to formal methods to understand them. In Figure 3 (a) the output of system 1 is used as the input of system 2, and the output of system 2 becomes the input of system 1, creating a closed loop system. In Figure 3 (b) the interconnection between system 2 and system 1 is removed, and the system is said to be open loop. A system is said to be a closed loop system if the systems are interconnected in a cycle, as shown in Figure 2 (Åström & Murray, 2009).

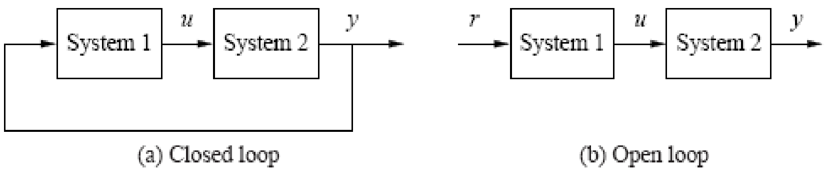

Figure 3: Open and closed loop systems

Feedback is an active concept in practically all area of activity. A feedback process is one in which the state of the system, or its output, determines the way in which the control has to be computed at any time instant (Neculai, 2005). Feedback has potential disadvantages as well. It can create dynamic instabilities in a system, causing oscillations or even runaway behaviour. Another drawback, especially in engineering systems, is that feedback can introduce unwanted sensor noise into the system, requiring careful filtering of signals. It is for these reasons that a substantial portion of the study of feedback systems is devoted to developing an understanding of dynamics and a mastery of techniques in dynamical systems. Feedback systems are ubiquitous in both natural and engineered systems. Control systems maintain the environment, lighting and power in our buildings and factories; they regulate the operation of our cars, consumer electronics and manufacturing processes; they enable our transportation and communications systems; and they are critical elements in our military and space systems. For the most part, they are hidden from view, buried within the code of embedded microprocessors, executing their functions accurately and reliably. The term control has many meanings and often varies between communities. We define control to be the use of algorithms and feedback in engineered systems. For example, the thermostat, in particular, is a simple example of feedback control that everyone is familiar with. The device measures the temperature in a building, compares that temperature to a desired set point and uses the feedback error between the two to operate the heating plant, e.g., to turn heat on when the temperature is too low and to turn it off when the temperature is too high (Åström & Murray, 2009). Another representation of feedback loops is optimal control and estimation in feedback loops.

3. INVENTORY CONTROL MODEL FOR PHARMACEUTICAL DISTRIBUTION

Pharma 4U gmbh is Swiss company, established in 2013. Main activity of this company is production and sale of innovative pharmaceutical products. 4U Pharma d.o.o. (http://4youpharma.com) is a branch in Serbia, aimed at pharmaceutical distribution for Balkan and neighbourhood countries. This company supplies wholesalers and pharmacies from Serbia, Macedonia, Montenegro, Bosnia and Herzegovina, Slovenia, Croatia, Albania, Rumania and Bulgaria. The company is constantly expanding, thanks to constant investment in development and monitoring of recent trends in the global pharmaceutical market.

Inventory management is an especially important for 4U Pharma d.o.o., as it is core activity of the company. At the end of every year company's logistics manager creates monthly sales forecast for next year. This forecast is based on historical data from previous years and manager's experience. At the beginning of every month customers from all countries deliver their stock reports. Ordering quantities and ordering periods are calculated in accordance with Fixed Order Quantity (FOQ), defined by supplier for each product (brand). There are more than one FOQ for each product and unit price depends on the ordered quantity. Order quantities are based on cumulative sales forecast for products of the same brand for different countries. Logistics manager orders articles of the same brand in total quantity for all countries, with remark about language for packaging and instruction. The company does not hold stocks and products are immediately transported to the clients, after customs and analysis. Production lead time is between 90 and 120 days, transportation lead time is up to 7 and custom and analysis 21 days. Total lead time, from order to delivery, is between 118 and 148. Additionally, manager negotiates about shortening of deadlines and price.

Ordering problem can be defined as follows: it is necessary to determine order quantities and ordering periods for each product (brand) for all countries, in accordance with FOQ, in order to provide enough inventories to cover monthly sales forecast, and to minimize distribution costs. Inventory management system is modelled in order to solve this problem. The system is modelled based on the feedback control methodology. During the model creation, all elements of a feedback loop are created (Figure 4).

Model is implemented in spreadsheet and procedures are automated through Visual Basic for Application (VBA). Spreadsheets are inexpensive and run on machines of modest specification. Due to ease of learning, usage and a great possibility for complex analyzing, spreadsheets have been accepted by many users at all levels, from beginners to experts (Lawson et al. 2009). Spreadsheets can be effectively used for analyzing logistics and supply chains issues. Usage of spreadsheets as logistics decision making software tool has exploded in the last two decades, driven by the need to optimize and integrate the supply chain. These tools are extremely effective in determining the optimum number of distribution locations, the appropriate mix of transportation modes, production scheduling, inventory optimization, product rationalization and strategic planning exercises (Smith, 2003). Spreadsheet software, notably Microsoft Excel, allows analysis from many different perspectives and can be modified and enhanced to reflect new situations and options. Moulder develops a baseline model according to current operations, creates alternative scenarios and compares those scenarios to the baseline. Non-quantifiable factors and soft costs are also considered to develop a complete analysis. Using spreadsheet, moulder can analyze the impact of business decisions on any number of variables, such as: logistics strategies, flow planning, inventory control, allocation and aggregate planning and network design and planning. Also, spreadsheet charts and graphs are excellent tools to provide visual impact to the logistics problems analysis. The effective use of graphs can aid in understanding the models' results. Contrary to the traditional logistics software, that may not always provide the flexibility required, spreadsheet allow analysis from many different perspectives and can be continually modified and enhanced, to reflect new situations and options. The user can add complexity to the model, in compliance with the increase of experience and knowledge about the process. Spreadsheet models can be used for strategic, operations or logistics planning and in many cases can be used simultaneously for all cases (Djordjevic & Vasiljevic, 2013).

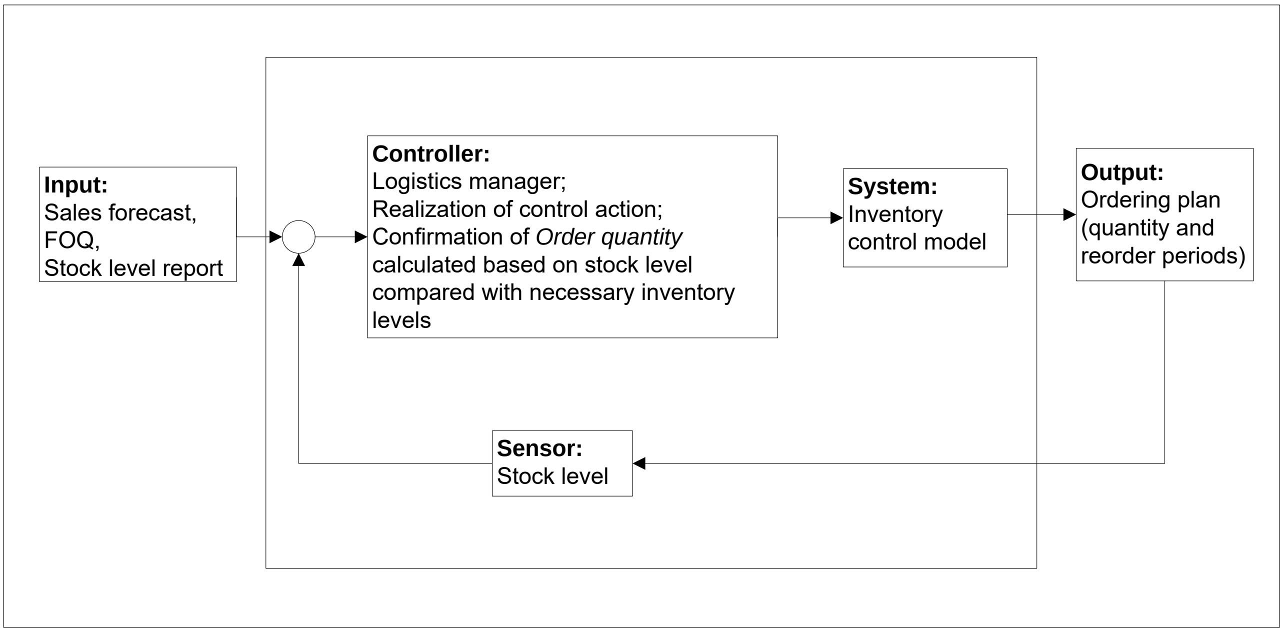

Figure 4: Elements of a feedback loop for inventory control model

Input elements for feedback control systems model are sales forecast, FOQ and stock level report (Figure 5). Monthly sales forecast is created at the beginning of year for entire next year, based on historical data from previous years and manager's experience. FOQ is defined by supplier. There are more than one FOQ for each product and unit price depends on the ordered quantity. At the beginning of every month, each wholesaler and pharmacy (customers from all countries) sends a report about stock level status to 4U Pharma's logistics manager. This report is prescribed form and format in Excel spreadsheet.

No.	Month	Sales forecast	FOQ	Stock level report	Stock level
0				1.508	1.508
1	January	10.900	32.000	2.000	2.000
2	February	12.100	32.000	5.000	5.000
3	March	25.200	32.000	0	0
4	April	13.000	32.000	2.400	2.400
5	May	13.800	32.000	1.200	1.200
6	June	14.500	32.000	0	18.700
7	July	14.700	32.000	0	36.000
8	August	15.400	32.000	0	52.600
9	Septemb	16.100	32.000	0	36.500
10	October	16.900	32.000	0	51.600
11	Novembe	17.200	32.000	0	34.400
12	Decemb	18.600	32.000	0	15.800

Figure 5: Input elements of inventory control model

In addition, monthly stock level has to be calculated. As stock level report is received at the beginning of month, it corresponds to the level at the end of previous month. Stock level for current month is calculated as sum of stock level quantity at the end of previous month and planned input and reduced for forecasted sale. In that way model covers whole year, even future months, where stock level is calculated based on planned delivery (input) and forecasted sale (output). Column *Stock level* (Figure 5) represents stock levels for all months in observation period at one place, which are calculated in described way. In this way, we define the sensor function of model, which prepares data for comparison in the model comparator.

Article	LT (months)	AVG inventories	AVG sale
BABYTOL_D3	5	39.250	15.700

No.	Month	Sales forecast	FOQ	Stock level report	Stock level	Order quantity	Planned input (stock)	Realized input (stock)
0				1.508	1.508			
1	January	10.900	32.000	2.000	2.000	32.000	0	
2	February	12.100	32.000	5.000	5.000	32.000	0	
3	March	25.200	32.000	0	0	32.000	0	
4	April	13.000	32.000	2.400	2.400	0	0	
5	May	13.800	32.000		0	32.000	0	
6	June	14.500	32.000	0	17.500	0	32.000	
7	July	14.700	32.000	0	34.800	0	32.000	
8	August	15.400	32.000	0	51.400	32.000	32.000	
9	Septemb	16.100	32.000	0	35.300	0	0	
10	October	16.900	32.000	0	50.400	0	32.000	
11	Novembe	17.200	32.000	0	33.200	0	0	
12	Decemb	18.600	32.000	0	14.600	0	0	

Figure 6: Spreadsheet inventory control model

Unusually long lead time (LT) indicates that order quantity has to be calculated based on inventory levels and sales forecast for all months between current period (t) and delivery period (t+LT). Comparator is used to determine the difference between necessary inventory levels for observed months and actual state of stock. Defined differences in the output of comparator are used for making final decisions about quantities of items that will be ordered and delivered to each wholesaler and pharmacy and time periods when orderings have to be realized (reorder periods). According to comparison algorithm (Figure 8), stock levels are compared with necessary inventory levels. Necessary inventory levels consider that demand should always be satisfied. Based on these differences, order quantity and reorder periods are calculated and presented in column *Order quantity* (Figure 6), which now realizes function of the model controller.

Article	LT (months)	AVG inventories	AVG sale
BABYTOL_D3	5	39.250	15.700

No.	Month	Sales forecast	FOQ	Stock level report	Stock level	Order quantity	Planned input (stock)	Realized input (stock)
0				1.508	1.508			
1	January	10.900	32.000	2.000	2.000	32.000	0	
2	February	12.100	32.000	5.000	5.000	32.000	0	
3	March	25.200	32.000	0	0	32.000	0	
4	April	13.000	32.000	2.400	2.400	0	0	
5	May	13.800	32.000		20.600	32.000	32.000	32000
6	June	14.500	32.000	0	6.100	32.000		
7	July	14.700	32.000	0	23.400	0	32.000	
8	August	15.400	32.000	0	40.000	0	32.000	
9	Septemb	16.100	32.000	0	23.900	0	0	
10	October	16.900	32.000	0	39.000	0	32.000	
11	Novembe	17.200	32.000	0	53.800	0	32.000	
12	Decemb	18.600	32.000	0	35.200	0	0	

Figure 7: Input realized earlier then it is planned

Column *Realized input* is used in cases when order arrives earlier or later than expected. In those cases, whole model is recalculated automatically. For example, if ordering is realized in January and LT=5 months, then ordered quantity is delivered after five months, in June (Figure 6). However, if delivery of articles ordered in January is realized earlier, in May, then stock level is increased and ordering plan has to be changed (Figure 7), in accordance with comparison algorithm (Figure 8).

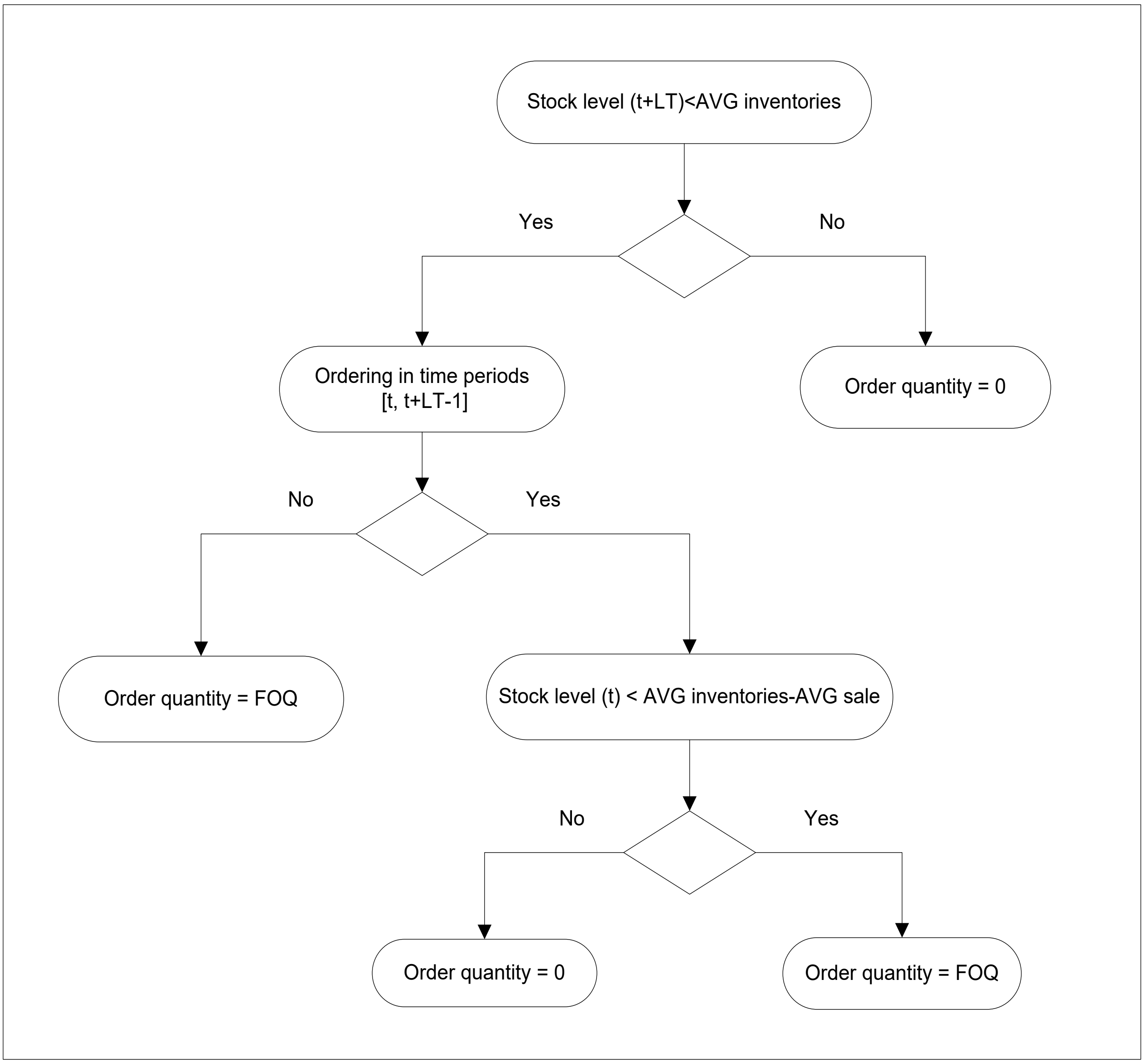

Figure 8: [*]Comparison algorithm

Model controller function is realized in position of logistics manager. His control role is to confirm order quantity for each product and if it is necessary to make a change of order, in accordance with FOQ, in order to get a lower price. Manager compares and control calculated order quantities in compliance with stocks level, prices, sale forecast, etc.

When quantities are approved, order is realized and sent to production, to 4U pharma gmbh. These actions as an effect has inventories planned level filling for all clients, wholesalers and pharmacies from different countries. Additionally, when order quantity and delivery is confirmed from production plant, whole quantity (FOQ) is assigned to the countries and clients (Figure 9). In this manner, logistics manager controls distribution of ordered quantity, which provides articles necessary for customer requirements fulfilment.

[*] AVG inventories - average inventories = (AVG sale * LT)/2 AVG sale - average sale for one year

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2			2016											
3			Januar	Februar	Mart	April	Maj	Jun	Jul	Avgust	Septembar	Oktobar	Novembar	Decembar
4		BABYTOL_D3	0	0	0	0	0	0	0	32.000	32.000	32.000	0	32.000
5		BB01BLSRB01					18000	20000						
6		BB01BLMKD01					13000	8000						
7		BB01BLENG01					1000	4000						
8		BABYTOL_D3_K1	0	0	0	0	0	0	32.000	0	0	32.000	0	0
9		BB01BLSRB02						20000						
10		BB01BLMKD02						6000						
11		BB01BLENG02						6000						
12		PROBIO_CHOCO	0	0	0	0	0	0	0	0	0	0	0	0
13		PB01BLSRB01												
14		PB01BLMKD01												
15		PROBIOChoco_C_Zn	0	0	0	0	0	0	32.000	32.000	0	32.000	0	32.000
16		PB01BLSRB02						12000						

Figure 9: FOQ quantity assignment

4. CONCLUSION

Many professionals, as well as beginners, from different fields make important decisions based on spreadsheet analysis, and organizations rely on them in record keeping, forecasting, analysing, decision making etc. Spreadsheets are an indispensable tool for simple, quick and easy processing and data analysis for activities of planning, modelling and control of inventories. Apart from logistics, spreadsheet models have a great importance in many other disciplines and fields such as finance, quality management, human resources, quantitative methods and etc. Spreadsheet modelling can be very simple or very complicated and prone to errors and consequently cause of bed decisions, in dependency of how much is moulder familiar with model developing methodology and data organizing in control models. Modern control theory and feedback control system provide basic concepts and elements that can be used for model creation.

Management of pharmaceutical inventory and pharmaceutical distribution have become a major challenge for pharmaceutical companies, as they simultaneously try to reduce costs and improve customer service level in an increasingly competitive business environment. Implementation of modern control theory and feedback control system logic can make inventory control of pharmaceutical articles easy and effective.

Focal point of this paper is inventory control in pharmaceutical distribution company, with an emphasis on order quantities and reorder periods, which have to satisfied specific constraints, described in the paper. As it is presented, inventory control system with feedback is implemented in spreadsheet. This spreadsheet model allows analysis from many different perspectives and can be modified and enhanced to reflect new situations and options. We have developed baseline model that enables alternative scenarios creation and compares those scenarios to the baseline. The results obtained from the model are used for procurement planning for more than 50 products per country for several countries from East-Central Europe for the year 2016.

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STATIC CODE ANALYSIS AND REPORTS BASED APPROACHES FOR SPREADSHEET ERRORS DETECTION

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Abstract: *Spreadsheet programs represent one of the most successful end-user software development tools, used for a variety of purposes. Professionals from different fields make important decisions based on spreadsheet models, simulation, analysis and organizations rely on them in record keeping, forecasting, analysing, planning etc., although, the statistics say that there are many errors in spreadsheets. Considering that the quality of business decision makes difference between success and failure, one must be sure that a spreadsheet doesn't contain an error that could get the decision maker to think of a problem in a wrong way. Consequently, spreadsheet risk awareness has been significantly increased over the last two decades and researchers have proposed a number of approaches, techniques and automated tools aimed at supporting end-users in error detection and debugging. In this paper focal points are spreadsheet error detection approaches from category static code analysis and reports. Four different approaches are presented and the gap that enables existing errors not to be found is discovered, which leaves space for future research in order to narrow the gap, especially in database manipulation field. Some of the approaches mentioned are concerned with units and types of the data, some are dealing with dimensions of the data and some of them are dealing with both. Since most of them are very specialized, not any of them can be marked as the best, since each one of them is used in a special area. Correspondingly, the goal of this paper is to recognize positive aspects of existing approaches and combine them into universal method applicable on more groups of error detection problems.*

Keywords: *spreadsheet errors, error detection, static code analysis, reports*

1. INTRODUCTION

Spreadsheet applications represent the most successful example of developing applications by the end user. The great advantage of spreadsheets is that they allow professionals from non-programming areas to create their own tools to support their business and to apply their domain expertise. The tools developed in this way are often available very soon, unlike many other applications used in business and that have to be developed by special IT departments. However, even if spreadsheets have many advantages as an environment that provides fast development of business applications, it leaves a lot of space for errors. Some more recent papers about spreadsheet errors, like the one by Jannach, Schmitz, Hofer and Wotawa (2014), show that there was at least one error found in every single spreadsheet they have tested. Sometimes, these errors don't affect the business, and on the other hand, there are spreadsheets used for decision making in very important situations, so every error of any type could make a difference between survival and disaster of a company, or even greater consequences.

A feature of developing their own tools that was given to end users has certain advantages, like flexibility, independence, development speed, lower risk of communication problems. But, there are also some flaws, and the greatest of all of them is possibility to create spreadsheet tools with errors, as described by Luckey, Erwig and Engels (2012) and Cunha, Erwig and Saraiva (2010). As the total number of spreadsheet users is a lot greater than the number of programmers, and as their needs for applications are great, the number of spreadsheet applications created every day is very great too. However, end users are not trained enough to check their applications for errors and that causes development and usage of their applications even on real data, even if they have errors. In order to minimize risks, spreadsheet experts have developed various approaches for avoiding, detecting and correcting errors in spreadsheets. It is possible to lower the risk by investing into education and training of end users, then, by creating organizational procedures for evaluation and development of spreadsheet applications, and, finally, by developing support to end users that will help them to identify errors while creating the spreadsheet tool (Jannach et al., 2014).

This paper highlights static code analysis and reports. The main goal of this paper is to present available solutions for analysis and to reveal the gap for further research and development of an approach that would enable, if not eliminating, then at least narrowing the gap between the errors that occur and the ones that can be found by using some of existing methods.

2. TYPES OF SPREADSHEET ERRORS

Errors in spreadsheets can be classified based on various criteria. Differing error types is important because each error type demands another method for detection. Errors can be divided into two main groups: qualitative and quantitative. Quantitative errors most often come as a result of a numerical error that could lead to wrong end results. On the other side, qualitative errors occur because of wrong spreadsheet design, for example double entries or few entries in one cell.

According to Teo and Tan (1999), quantitative errors can be mechanical, logical and omission errors. Mechanical errors are those that occur because of simple things like wrong number entry, watching the wrong cell address or selection of the wrong area of cells. The main reason why users make these mistakes is lack of attention, stress, work overload or bad work environment. Logical mistakes are more complex and they occur because of wrong formula. Wrong formula comes as a result of wrong algorithms caused by the lack of domain expertise. For example, it is possible to determine price only by adding variable costs, while forgetting about fixed ones. The consequence is very clear, the product might be sold at a price that doesn't cover total costs for its production. For detecting spreadsheet errors it is required to have more experience than for detecting mechanical errors because it requires, except knowing spreadsheet technique well, also knowing the business process. Finally, there are omission errors. They are caused by not including some important element in the model. As with logical errors, they are not easy to find and it requires both, knowing the spreadsheet techniques well, but also understanding the business processes.

On the other side, according to Rajalingham, Chadwick and Knight (2008), spreadsheet errors can be divided into few groups. System generated errors are those generated by spreadsheet tool or a bug in software. Their creation is above users' control, but, if users are aware of them, they can perform steps to avoid them. Errors generated by end users can be prevented, detected and corrected. They can be qualitative and quantitative. Quantitative errors can be accidental, as errors and omissions created by lack of attention, like typing errors. They can be caused by spreadsheet designers or end users. Designer could select a wrong field, double some entry or create an omission error. When it comes to end user, they can be divided into two groups: those who enter the data and those who read the data. Both groups can create errors of the same type as the developer. The second type of quantitative errors is a reasoning error that could be an error caused by not knowing the domain enough, like not understanding the business process or mathematical way of displaying. Quantitative errors include errors during implementation process, that can be syntax and logical errors. The other group of spreadsheet errors is qualitative errors. They can be semantic and errors for future maintenance. Semantic errors are those with wrong structure and time – entering data that is not up-to-date, while maintenance errors are those that make data entry more difficult, but also other types of upgrades.

3. CATEGORIES OF APPROACHES FOR SPREADSHEET ERRORS DETECTION

For identifying errors in spreadsheets, many approaches and tools were primarily developed and used for the same cause in software engineering. However, as it was mentioned above, the feature of spreadsheet error detection is in immediately visible results, the user gets visual feedback as a result of applying function on some data. Spreadsheets are different than common program languages because all the calculus is done within the cells that contain formula and they are performed with data contained in other cells. Also, in spreadsheet, every datum has its physical position, but also its semantic of calculus. Potential errors can be found based on sign in data header that puts every single datum into some context and then it is possible to make conclusions about characteristics of results of certain formula.

The technology of spreadsheets enables users who come from different areas and levels of spreadsheet knowledge to create their own models. Most of the users don't know even the basics of spreadsheet model quality assurance. Because of that, this process has to be done in a way that requires minimal or no end-user participation in a way that doesn't depend on the level of expertise of the user.

Approaches to software quality assurance (QA), applicable to spreadsheets, are categorized in two major groups (Đorđević and Lečić-Cvetković, 2015):

- Identifying and correcting errors – techniques and tools designed to help users to detect errors, identify its cause and suggest correction. These tools are used by spreadsheet creators, auditors and reviewers, during or after development of spreadsheet model.

- Avoiding errors – contains techniques and tools that support spreadsheet development without errors. They are applied during the spreadsheet model development process.

Finer-grained categorization of the existing approaches to automated spreadsheet quality assurance can be seen in the Table 1.

Table 1: Automatic spreadsheet quality assurance approaches categorization (Đorđević and Lečić-Cvetković, 2015):

Nº	Spreadsheet QA approaches	Identifying errors	Avoiding errors
1.	Visualization based	x	X
2.	Static code analysis and reports	x	X
3.	Testing	x	
4.	Automatic localization and correction	x	
5.	Model based development		X
6.	Design and maintenance support		X

Categories 1 and 2 can be used for identifying and avoiding errors. For example, good visualization of dependencies among cells helps users to identify the problem, but also to identify cells that have high chances of creating errors. Static code analysis discovers existing errors like a reference to an empty cell or listing formulas that are too complex. On the other side, 3 and 4 are used for identifying and localization of already made errors. Methods 5 and 6 are made for avoiding errors, for example, by refactoring or adding levels of abstraction.

4. STATIC CODE ANALYSIS AND REPORTS

Static code analysis is the spreadsheet QA area that has major usage options and can be divided into three subgroups: unit and type inference, spreadsheet “smells”, static analysis and commercial tools, as it is explained by Đorđević and Lečić-Cvetković (2015). However, these approaches are often combined in order to discover more errors.

Static code analysis and reports based approaches analyze formula in spreadsheets and show potential errors or wrong spreadsheet design that could lead to future errors. This approach doesn’t analyze cell values. The approach is based on formula and their dependencies, their static labels and other structural characteristics of the spreadsheet.

Unit and type inference is an approach that belongs to static code analysis and report based approaches, and the main idea of this method is getting information about cell units and using them in order to make a conclusion if the calculation makes sense or not. In order to get information about units, headers are used. Erwig and Burnett (2002), in their first papers from this field, were only telling about ways how to get information based on header, and later they developed procedures how to actually perform that without user efforts. The newer papers of these authors are directed to label analysis and attempts to get them down to known units and to decide on calculations based on that. Some of them require user to enter units, while the newest of them even have systems for unit recognition based on the label.

The group of spreadsheet “smells” methods is contained by methods that don’t “say” that in some spreadsheet there is an error nor that there will definitely be some error in future. They are designed in a way to recognize spreadsheet parts where there is too much space for errors, because of spreadsheet design: long formula, too many references to another spreadsheet, constant values in a formula, etc.

Finally, techniques of static code analysis are often used as a part of commercial tools. Many of them can be seen in MS Excel in order to mark “suspicious” formula that maybe shouldn’t be where they are, or they could be made in some other way, as it was presented by Jannach, Schmitz, Hofer and Wotawa (2014). In the next section of this paper, methods developed by spreadsheet engineering experts are presented, by highlighting virtues and flaws of their methods, in order to identify directions for future development.

5. STATIC CODE ANALYSIS AND REPORTS APPROACHES OVERVIEW

The basic principles of identifying errors in spreadsheets based on unit and type inference are presented in Erwig and Burnett (2002). This approach presents one of the basic methods for spreadsheet errors detection from static methods and is based on an idea of identifying errors related to forbidden combinations of units. The goal of this paper was to discover errors in system if they occur during entry, at the moment of data entry. Errors are identified based on units, where unit is a label entered in table header. There is an acknowledgement of the existing need for functions of higher level, but it is limited only to first level functions. These functions are the ones that make a result some value that is in the unit of same level and it doesn't include option of using functions where a new dimension is created as a result of applying function on existing values. Because of the striving to achieve greatest functionality possible, the authors made four limitations set (Erwig and Burnett, 2002):

- The first one includes inference mechanism that provides immediate feedback of visual type in order to know if the formula is error-free.
- The second limitation is that inference system uses labels and functions that users use.
- The third limitation is related to formal unit labelling. An additional limitation is a mechanism of inference that does it function without need to predefine formal units.
- The fourth one defines a mechanism that is applied to real spreadsheets created by users and doesn't include assumption that users will use the right formula in a right way.

Headers are labels that assign units to a group of cells. A cell can have few headers. A header is explicit information about cells to which it belongs and based on its units are checked. Header can be defined by expected entry information, based on formatting and position in spreadsheet. Headers and cells can have different relations. Dependable units are present on few levels. For example, higher level unit – a car, can be a limousine, roadster, a sports-utility vehicle etc. Relations "and" and "or" refer if a cell can have one or both units. The logic of this model is based on defining well-formed units and differing them from those that are not.

Well-formed unit is 1, as an universal unit, then, unit that doesn't have a header. If a cell has value *v* and a header *z*, then, *z(v)* is a well-formed unit. One example includes "and" operations that combine values without common predecessors. Also, well-formed unit is a unit that comes as a result of "or" operation when two units have common predecessors. According to Erwig and Burnett (2002), rules for unit inference are:

- If a cell doesn't have header, the unit is 1;
- If cell a has header b that contains value v and has a well-formed unit u, then *u(v)* is a unit of a;
- If a cell has a reference to some other cell, it will also have the cell's unit;
- Each mathematical operation has its own definition of combining units.

In accordance with rules and limitations, an algorithm for unit inference was created, based on units and the operation that are used in formula. It is logical that adding and reducing are done over data of same units and that result has the same unit. The complete algorithm is based on an idea to get well-formed units from operations. If it is not possible, the system will report error.

Unlike the previously presented paper, Ahmad, Antoniu, Goldwater and Krishnamurthi (2003), based their paper on an idea that spreadsheets are made of cell locations, values and expressions. Header is a common unit for a group of cells. The presumption is that all headers are known. There are two types of relations "is-a" and "has-a". "Is-a" is used for belonging to a type, for example "apple is a fruit", and, "has-a" tells that header has some characteristic "apple has an attribute colour". Units are defined in the same way as in the previous model. In order to use the method, the authors have defined four rules for "calculating" units in the model (Ahmad, Antoniu, Goldwater and Krishnamurthi, 2003):

- The first rule is that each cell has one or zero "is-a" relations. If no, then it is "top" and the unit is the header label. Otherwise, it is a concatenation of header label and its cell label.
- The second rule says that cells that contain values and are not in header get units from their headers. Each cell containing user data must have at least one "is-a" header. Except that, there must be at least one "is-a" header with "has-a" relation. If there is only one "is-a" header, unit of a cell is formed by concatenating header unit and the header label to get "is-a" part and by adding existing attribute in the end. If there are few "is-a" headers, every "is-a" has its own hierarchy, and results are combined.
- The third rule explains that cells that contain only references are taking units of referenced cells.
- The fourth rule explains that cells that contain formula get unit based on rules of mathematical operation.

Adding is defined in situations when there is an "is-a" operation with common "has-a" relation, adding and reducing with common "is-a" with different "has-a" part. The defined didn't include the case when both "is-a" and "has-a" are different. Based on functioning of adding and reducing, it can be said that any binary operator calculates units correctly in two cases – common "is-a" part – result of the operation is combination of two different "has-a" parts, also defined for common "has-a" parts. The authors also defined the "&" operation. The spreadsheet has an error if it comes between two units with common header ("top" not included). Examples of these rules, according to Ahmad, Antoniu, Goldwater and Krishnamurthi (2003), are given below (the mark for "has-a" part is "{}", and for "is-a" part - "[]"):

Fruit[Apples]{Quantity}+Fruit[Oranges]{Quantity}=Fruit{Quantity}

In other words, adding quantities of apples and oranges results as a quantity of fruit.

Fruit[Apples]{Costs}+Fruit[Apples]{Profit}=Fruit[Apples]{Costs◦Profit}

If costs of apples are added to their profit, there will be a new unit – result of operation ◦ on cost and profit. A situation not covered with this model can be presented as:

Fruit[Apples]{Costs}+Fruit[Oranges]{Profit}

This method also covers a case with multiple relations of subtype:

Fruit[Apples][Bad]+Fruit[Oranges][Bad]=Fruit[Bad]

“Bad” is a subtype, and not an attribute. The result of adding is “Bad Fruit”. Reducing is defined in the example below:

Fruit[Apples[Total]]{Quantity}+Fruit[Apples[Bad]]{Quantity}=Fruit[Apples]{Quantity}

Reducing “bad apples” from total quantity will result with quantity of “good apples”, but, it is impossible to conclude that unless it is predefined that only two subtypes of apples are “good” and “bad”. The authors also defined the case with common subtype, but different attribute:

Fruit[Apples]{Revenue}-Fruit[Apples]{Costs}= Fruit[Apples]{Revenue◦Costs}

The result is a common type-subtype part with an attribute received as a result of operation over two different attributes. In case of multiplication, a situation simplest described on shapes is defined:

Shape[Square]{Width}xShape[Square]{Height}=Shape[Square]{Width•Height}

The result is a common subtype part, and it gets a combination of different attributes. The case of different subtypes and same attributes is not defined, but, the system won’t report error in this case. The concatenation operation, often used in spreadsheets can be used only for elements with headers that are not common and at most one of them has an attribute.

A different approach is given by Chambers and Erwig (2009), where error identification is performed on three levels:

- headers;
- labels that simplify units and search for already known units and inferring based on it;
- inference on dimensions, by checking all the cells with formula and getting final dimensions by rules described in the paper.

The authors defined dimensions for many operations that can be performed in spreadsheets: adding, multiplication, “if” function, count, reference and “regular” cell's dimensions (Figure 1).

$$\boxed{S,H \vdash a : d}$$

NoHdr
$$\frac{H(a) = \varnothing}{S,H \vdash a : \delta}$$

SingleHdr
$$\frac{H(a) = \{a'\} \qquad S(a') \Rightarrow d}{S,H \vdash a : d}$$

DoubleHdr
$$\frac{H(a) = \{a_1, a_2\} \qquad S(a_1) \Rightarrow d_1 \qquad S(a_2) \Rightarrow d_2 \qquad d \in d_1 \otimes d_2 \qquad \mathscr{V}(d)}{S,H \vdash a : d}$$

$$\boxed{S,H \vdash e : d}$$

Val
$$\frac{}{S,H \vdash v : \delta}$$

Ref
$$\frac{S,H \vdash (a, S(a)) : d}{S,H \vdash \uparrow a : d}$$

Count
$$\frac{S,H \vdash e_i : d}{S,H \vdash \mathbf{count}(e_1, \ldots, e_n) : \{\}}$$

If
$$\frac{S,H \vdash e_2 : d \qquad S,H \vdash e_3 : d}{S,H \vdash \mathbf{if}(e_1, e_2, e_3) : d}$$

Add
$$\frac{S,H \vdash e_1 : \{b^n_{f_1}\} \cup d \qquad S,H \vdash e_2 : \{b^n_{f_2}\} \cup d \qquad c_1 = f_1/f \qquad c_2 = f_2/f}{S,H \vdash c_1 * e_1 + c_2 * e_2 : \{b^n_f\} \cup d}$$

Mult
$$\frac{S,H \vdash e_1 : d_1 \qquad S,H \vdash e_2 : d_2 \qquad d = d_1 \bowtie d_2 \qquad \mathscr{V}(d)}{S,H \vdash e_1 * e_2 : d}$$

$$\boxed{S,H \vdash (a,e) : d}$$

Cell
$$\frac{S,H \vdash e : d \qquad S,H \vdash a : d}{S,H \vdash (a,e) : d}$$

Figure 1: Inference rules (Chambers and Erwig, 2009)

In case that the dimension cannot be defined, the system reports an error. Also, exponents of existing dimensions are included. The logic of the approach on the example is presented in Figure 2.

F5 | fx =B5+MAX(F2*60-C5,0)*D5

	A	B	C	D	E	F	G
1							
2				Hours of use	15	25	35
3							
4	Plan	Base Fee	Plan Minutes	Usage Charge	Total		
5	Verizon	39	1000	0.025	39.00	51.50	66.50
6	Quest	49	1500	0.021	49.00	49.00	61.60
7	Xingular	29	500	0.026	39.40	55.00	70.60
8	IBN	0	0	0.034	30.60	51.00	71.40

Figure 1: Example of the approach used on spreadsheet (Chambers and Erwig, 2010)

In the Figure 2, cell F5 contains a formula "=B5+MAX(F2*60-C5,0)*D5". Authors applied the rule given in the Figure 1, labelled "CELL". The value has dimension based on formula it contains and its header. Header "Total" can represent a sum of different units, however, since these spreadsheets are from finance area, the guess is that it is $. The conclusion is that F5 should have $ unit, but it is not confirmed that the result of the formula will be in $. Because of that, addition rule is applied, but after the reference rule. Based on that, B5 part has dimension $, like in original formula.

The other part of formula uses rule for unit inference in multiplication. Field D5 doesn't have a unit, and dimension of second factor is received from addition rule and it can be also applied to "max" function. If the operation is watched, it is clear that it has few parts. In F2, there are hours, and, it is logical that multiplied by 60, the result is in minutes. Then, it is reduced by minutes. Then, by the rule of multiplication, in order to get $, it must be in $/min, so it can be said that D5 has $/min unit, which is acceptable, if the logic of the model is had in mind. Finally, adding of two values in $ will result in $. In this case, no errors are reported.

Another example for showing functionality that is not contained by previous example, is an example of adding values that have common basic unit, but their factors are different (centimetres and meters). Centimetres require multiplication with 0.01, so the system will report error, but it will be able to suggest a correction.

In a paper about identifying errors, Chambers and Erwig (2010) use a combination of mentioned methods, for example, there is an approach of integration of dimension and unit inference. First, header inference, then, understanding labels, identifying dimensions and label axis, then, combined inference based on labels and dimensions. Header inference analyzes structure of spreadsheet and returns a set of headers for each cell. Header represents an address of other cell. One cell can be a header for many cells, and any cell can have zero, one or more headers. In this paper, headers can be vertical and horizontal. Header inference is performed by analyzing spatial relations between the formulas. Label inference relates to a situation when dimensions are derived based on its header's label. Labels are separated into words that are translated into dimensions and then all of them are combined into one dimension.

When identifying labels and dimensions, there are three different cases (Chambers and Erwig, 2010):

- no dimensions,
- one dimension and
- two dimensions.

In the first case, only labels are watched. The second case represents a combination of label and dimension inference. An axis is determined for each dimension and label. A cell has a combination of characteristics received as a result of separate use of mentioned methods. The third case is the same, but for both of them, dimension inference is used.

The combination of labels and dimensions inference has many levels: value inference, header inference, expression inference and cell inference. The advantage is that it checks only if units are the same. This is easier because dimensions are combined into one, so it is easier to determine units for multiplication, where it is the only condition to have matching units.

The last feature of this method is finding primal dimension, it enables to, if possible, to find different units for same dimension and to express one through another. If impossible, the system will report error.

6. ADVANTAGES AND DISADVANTAGES OF STATIC CODE ANALYSIS AND REPORTS APPROACHES

Approaches described in this paper have virtues and flaws which make them more or less convenient for certain situations. Erwig and Burnett (2002) presented the base of this whole category. Based on header, unit inference is performed and then, errors are reported if no rule of well-formed units can be applied. The good side is that errors are reported immediately after entry. The main flaw is a narrow scope of different spreadsheet and formula that can be checked.

In paper Ahmad, Antoniu, Goldwater and Krishnamurthi (2003), authors proposed approach, with relations “is-a” and “has-a”, and based on them, rules for unit inference based on operations are used. There are different cases, depending on which characteristics of formula elements are common and which are not, and based on that, resulting units are defined. Errors are reported in case that there is no combination of common characteristics and operations found. Advantage of this method is that it can be applied in many fields, without knowing much about the area where spreadsheet is used. It doesn’t require predefining units and it is not restricted to only one or small number of areas. The main flaw of this approach is the lack of header inference, it is necessary to write dimensions in the same way every time. Also, small number of operations is defined: adding, reducing, multiplication and dividing, but also concatenation.

According to Chambers and Erwig (2009), the analysis is performed in three steps. First, on header level, the second is based on labels, which are analyzed by parsing and finding known units that are used. The third level is based on formula in cells which have rules defined. The approach has three levels and it makes it more efficient than each of them separately. Shortcoming is that it includes assumptions, as it is shown in the example “Total” header where it is guessed that it is $. The positive is that values of same dimensions can be compared even if indifferent dimensions.

The approach shown by Chambers and Erwig (2010) can be characterized as the most complete. This approach presents a combination of different methods and contains the previous methods. Except mentioned, approach has two new features: it doesn't detect errors based on well-formed units, but it combines all units into one, and all it takes is these dimensions to match and the cell will be considered correct. Dimensions are inferred in three situations: horizontally and vertically, horizontally or vertically, or no dimensions at all.

All the approaches are used for simple spreadsheet models and simple calculus in maximum two dimensions. Calculus is checked and cells that might contain errors are reported. They are used for only one table in a spreadsheet, while they cannot be used for putting few tables into one. Also, there are no checks if there are all the elements required in the formula. As it can be concluded based on the approaches presented, there is enough room for improvement of these methods that will enable discovery of errors that occur often.

7. CONCLUSION AND FUTURE RESEARCH

Analysing existing approaches and methods for error detection and potential types of errors that might occur, future research should be pointed to approaches that will enable finding errors that are not included in mentioned methods and on implementing existing methods in new situations, aiming to improve spreadsheet models' reliability.

Existing approaches were tested on a small number of spreadsheets and mainly require more or less efforts from end users in order to test the spreadsheet. The goal of future research is to minimize user efforts required in spreadsheet error detection process and lower dependence of data form in spreadsheet.

Future research directions also consider development of approach that will identify errors on many levels, especially those that were made during database manipulation. In case of database with many columns, each column represents a new dimension where the datum is located depending on its value. In existing models, one or two dimensions are checked, while in case of database, error check would have to be done in a large number of dimensions in order to check if some operation makes sense. If some operation over some data will get a result that is meaningful to the user. To be more precise, it is checked if it is possible to relate the result with some existing or a new dimension that represents a combination of the existing ones.

Another functionality of spreadsheets that is not checked enough, but yet, used very often, is "VLOOKUP" function, used for transferring data from one database to another by using common parts. Often, users skip some data in the formula which results in not finding a value that exists. Also, different formats in the database cause "VLOOKUP" not to find some value, even if it exists in the spreadsheet. The idea is to create an application that will check the type and scope of formula data, and in case of data in the same column, but not of the same format, it should report potential error.

Another potential improvement might be improving existing Excel methods for checking values and formats of adjacent cells. Potential options will be considered in the future, in order to add some new functionality that will lead to lowering error probability.

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AN OPTIMIZATION-SIMULATION APPROACH TO ADVERTISEMENT PLACEMENT PROBLEM

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Abstract: *A stochastic programming problem with a number of random parameters in the set of constraints is considered. An iterative optimization-simulation approach is applied as solving method. It consists of two phases: optimization phase, which includes solving a deterministic counterpart of the original chance-constrained problem, and a simulation phase in which the original constraints are checked using Monte Carlo simulation. One iteration corresponds to one scenario. If the decision maker is not satisfied with results, new scenario is generated in which the deterministic values of stochastic parameters are changed in the direction that will provide a more robust solution. Deterministic counterpart in the new scenario is formulated depending on the result of previous iteration. For that purpose, different heuristics are considered. The main goal is to provide a good insight on the optimization problem under uncertainty by performing relatively small number of iterations. General approach and results of the proposed framework will be illustrated on an advertisement placement example.*

Keywords: *Stochastic programming, Simulation, Chance constraints, Linear programming*

1. INTRODUCTION

Application of operational research techniques in marketing started with the famous theorem for marketing mix optimization in 1954 (Dorfman & Steiner, 1954). That pretty much opened the path for OR techniques implementation to marketing problems. Linear programming and goal programming became the first choices when talking about OR in marketing, and Markov models and various simulation techniques, as well as game theory, were applied in the 1960’s and 70’s (Montgomery, 1970). Even in these early days of interaction between OR and marketing, researchers observed the stochastic nature of marketing problems, through utilizing the theory of decision making under uncertainty (Pratt, Raiffa, & Schlaifer, 1995). Not much was done in the upcoming years on this field, but recently, due to substantially increased computational capacities of computers, modeling uncertainty through various estimation techniques has found its place in OR applications in marketing (Rossi & Allenby, 2003).

Consequently, stochastic programming is not new to marketing, but generally wasn’t the main focus of the researchers at the beginning. Nevertheless, it has sprung a new interest among researchers in various fields of marketing problems.

Even with the abundance of research material and the long history of marketing models, it is an observed fact that these models are rarely used for decision making in practice. Advertising, as a part of the marketing mix, was particularly researched, and researchers deemed its effects on sales and market share to be doubtful. This particular opinion was created due to concerns that advertising might have no effect on sales at all, but since (Clarke, 1976), (Leone & Schultz, 1980) and (Vidale & Wolfe, 1957) confirmed that advertising has a positive influence on sales, all suspicions on effectiveness of these models and its application in decision making could be dismissed. Naturally, a lot of effort was put into developing models that could optimize the allocation of an advertising budget, which is also the task at hand of this paper.

Still, because of the stochastic nature of marketing problems, many of them will remain intractable to ordinary mathematical solution (Kotler, 1963). But, complying with the saying: “When all else fails, simulate!” an optimization-simulation approach is put forward and applied to the advertising placement problem.

Stochastic programming allows decision makers to incorporate a measurable uncertainty in a model, which means e.g. that uncertainty can be expressed through appropriate distribution of data or in some other way.

Stochastic programming has applications in a great number of areas and classes of problems, and in this paper, a class of marketing models is considered, namely the marketing campaign model. The reason why the field of marketing is chosen, is due to stochastic nature of the marketing problems. Thus, the observed problem is a perfect match for the use of a new approach to stochastic programming that is being proposed. The task at hand will be to minimize the cost for a marketing campaign by placing advertisements in various newspapers, which is done exclusively through printed editions of newspapers and magazines, while reaching the needed views and scores both in total population, and within target groups.

As for the solving method, an original approach is proposed, an iterative optimization-simulation approach to stochastic programming.

The paper is organized as follows. Section 2 gives a short overview of stochastic and robust programming and shows how both of them fit into the proposed solving method. Section 3 is the part of paper where the model is formulated, i.e. mathematical model and its notation and a short explanation of the optimization task. Section 4 is reserved for detailed description of the proposed optimization-simulation approach. All the steps of the iterative process are presented, both in words and graphically. The results of research are presented in the Section 5. Concise results are given through tables and diagrams for every scenario used. Section 6 summarizes the conclusions.

2. STOCHASTIC AND ROBUST OPTIMIZATION

Every attempt of modeling a real life problem means facing an uncertain, incomplete or erroneous data. One can differentiate between stochastic and robust optimization when handling uncertainty in models. Robust optimization consists of several approaches for which common goal is to protect the decision maker from any uncertainty in the parameters and from stochastic uncertainty (Gabrel, Murat, & Thiele, 2014). The basic presumption of robust optimization is the existence of such constraints that must always be satisfied, no matter what the realization of the uncertain parameters are (Gorissen, Yanıkoğlu, & den Hertog, 2015). In addition, every uncertain parameter has to get its value from a predefined set.

Stochastic linear programming was first defined in 1955 (Tintner, 1955), and the same year, (Beale, 1955), (Dantzig, 1955) developed an approach that was based on recourse costs and the method was named linear programming with uncertainty. Several years later, (Charnes & Cooper, 1959) defined a new approach in stochastic programming called the chance constrained programming, which differed greatly from the previous two approaches.

There are different methods to incorporate uncertainty in a mathematical model. Theory suggests that most of them are based on defining a new deterministic counterpart, or deterministic replacement, of the original problem. As for solving these models, there is an approach of simplifying the real problem so it can be solved with standard mathematical methods; while on the other hand, there are simulation and optimization techniques that are commonly used in practice (Beyer & Sendhoff, 2007).

Nevertheless, stochastic programming is less conservative compared to robust approach, which is generally orientated on the worst-case scenario when creating a deterministic equivalent of the original problem. The previous statement is valid only on the condition that distributions of random variables in the model are known, or can be calculated. If that’s not the case, there are a lot of problems to be expected in solving the deterministic counterpart of the original problem, and often one won’t even be able to find any solution for such uncertain parameters. Still, as (Ben-Tal, El Ghaoui, & Nemirovski, 2009) state in their book, stochastic and robust programming are complementary approaches for optimization under uncertainty, which is the approach that will be used in this paper.

3. PROBLEM FORMULATION

The problem of selecting the optimal number of advertisements to be placed in different newspapers is considered. Besides the obvious task of determining the number of advertisements, their positions and size for every newspaper has to be determined as well, while reaching the needed views and scores both in total population, and within target groups. The goal is to achieve all these with the minimum cost possible. Daily, weekly and monthly newspapers, their total views, as well as rating for each newspaper for the targeted group are considered. Ratings are data with a stochastic nature, and are assumed to have a Gaussian distribution. The cost of advertising is set in accordance with real life data. The problem is formulated as a linear stochastic programming model.

Notation

I - Set of newspapers (daily, weekly and monthly)

J - Set of possible positions in all newspapers

P - Set of possible positions for every single newspaper

T - Set of target groups

S - Minimum number of unique advertisement views
c_{ij} - Price for each position in every newspaper
v_i - Number of newspaper views
r_{ik} - Newspaper rating for every target group
p_j - Visibility percentage for every advertisement position
t_k - Wanted rating for a target group
m - Minimum number of advertisement in i newspaper
h - Maximum number of advertisement in i newspaper
g - Minimum number of advertisement on j position
d - Maximum number of advertisement on j position

x_{ij} - Number of j advertisement in i newspaper

Mathematical model

With reference to introduced notation, the advertisement placement model is presented:

Minimize

$$f(x) = \sum_i \sum_{j \in P} c_{ij} x_{ij} \tag{1}$$

subject to constraints

$$\sum_i v_i \sum_{j \in P} p_j \sum_i \sum_{j \in P} x_{ij} \geq S \tag{2}$$

$$\sum_i \sum_{k \in T} r_{ik} \sum_i \sum_{j \in P} x_{ij} \geq t_k \tag{3}$$

$$\sum_{j \in P} x_{ij} \geq m_i \tag{4}$$

$$\sum_{j \in P} x_{ij} \leq h_i \tag{5}$$

$$\sum_i x_{ij} \geq g_j \tag{6}$$

$$\sum_i x_{ij} \leq d_j \tag{7}$$

Constraint (2) sets the minimum wanted total advertisement views; constraint (3) sets the wanted rating for every target group; constraints (4) and (5) set the minimum and maximum number of possible advertisement for every newspaper, respectively; and constraints (6) and (7) set the minimum and maximum number of possible advertisement that can be placed on the assigned positions for every newspaper, respectively.

4. OPTIMIZATION-SIMULATION APPROACH

The proposed solving method is an iterative optimization-simulation approach. It consists of two phases, the optimization phase, where scenarios are generated and the deterministic model is solved, and a simulation phase where the validity of scenario is checked.

Applying the robust approach to creating a deterministic counterpart of the original model will result in a model that is immune to uncertainty. Obtained solution will always be admissible despite any realizations of uncertain parameters. An obvious downside of this approach is that the value of the criterion function is the worst possible. This is why this approach is also called the pessimistic approach, or the worst-case scenario approach. In reality, realizations of uncertain parameters that result in a worst-case scenario are highly unlikely. The goal isn't to model an extreme case, but to handle general uncertainty and that is why the chance-constrained approach is used and combined with robust approach in the solving method.

This approach is about replacing an original problem with a new, deterministic model that will provide the best solution under the condition that constraints are satisfied with a predefined probability. Generating a new deterministic counterpart of the original model corresponds to one scenario. Obviously, this approach will require defining a considerable amount of scenarios that need to be checked, in order to find a scenario that will achieve the wanted probability of satisfying the constraints. The upside is that one's able to better understand the original problem with every iteration.

The second phase of the method uses the power of simulation to check the generated scenario.

Upon solving the deterministic counterpart of the original problem in the first phase, optimal solution is obtained, which is needed in order to determine the probability of satisfying the stochastic constraints. Next, a random deterministic value for every uncertain parameter from its predefined set with assigned distribution is selected. This way a matrix of random deterministic values of uncertain parameters is generated, or in other words, the randomness of stochastic data is simulated. The constraints are checked if they are satisfied or not by taking into account the deterministic values and optimal solutions of the scenario generated in the first phase.

These simulations are repeated N times, generating N of these matrices, inserting the numbers into the constraints and then calculating if they are satisfied or not. By counting the times when constraints were satisfied, the probability for satisfying stochastic constraints can be calculated, with the following formulae: (Number of cases when constraint was satisfied/Total number of cases N) *100. This is done for every constraint in model.

This approach works under the presumption that the decision maker is willing to accept a certain risk that the constraints won't be satisfied. In return, the value of the criterion function will be better than if the decision maker was to remove all uncertainty and accept the robust approach. If the decision maker is not satisfied with the results, a new scenario will be created, i.e. a new deterministic counterpart of the original problem, and the whole procedure will be repeated again. New scenario will be formulated depending on the results of the previous one, and the goal will be to find such a scenario that meets the minimum criteria set by the decision maker in terms of chance that constraints are satisfied, while trying the find the best possible value of the criterion function.

The main issue of the whole procedure is scenario generation and how to define a new deterministic counterpart of the original problem. There is no iron rule in scenario generation, and it is strongly suggested to use different heuristics. Particular heuristics used will depend on the nature of the problem that is considered, the assumed distribution of the random data, past data available, experience of the decision maker and of the specific problem that is being considered.

For every heuristic to be meaningful, a general target goal must be known, or set. Decision makers usually require a high percentage of constraints satisfaction. Therefore, stochastic constraints are usually divided into two groups. The first group is the so-called "hard" constraints group, and decision maker demands that these constraints must have p_i levels that are 100%. The second group is the "soft" constraints group and decision maker accepts a certain risk that these constraints won't be satisfied. Usual p_i levels for these set of constraints are above 90 - 95%. The idea of dividing constraints in LP model to hard and soft ones was first introduced in (Kendall, 1975) and is used in this paper as well. One can make further groups of constraints, but these are the general guidelines of how this specific problem was modeled in this paper.

Two starting scenarios should be the scenario with the expected values, and a robust scenario. Using these two scenarios as border cases provides the initial insight in the nature of the problem and stochastic data. The only thing that's left is to test different scenarios, and that is why iterative approach is very handy. If facing the usual problem of high p_i levels (above 90%), then sticking close to robust scenario provides the greatest possibility that constraints will be satisfied. Have in mind though that not getting to close to the robust scenario is also a prerequisite, because getting to close to this scenario will translate in a worse criterion function. Therefore, the general approach will be to make a tradeoff between the robustness of the model and the value of its criterion function.

The whole approach is summarized in Figure 1.

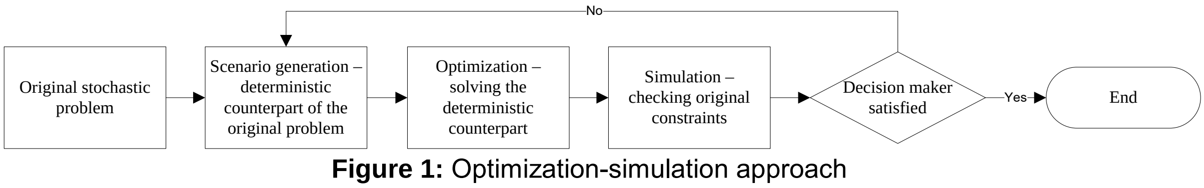

Figure 1: Optimization-simulation approach

The proposed solving method will be applied, namely optimization-simulation approach to stochastic programming, to the advertisement placement model presented in Section 3 and the results will be presented in the following chapter.

5. COMPUTATIONAL TESTING AND RESULTS

Let's take another look at the model presented in the section 3. The stochastic nature of the model is reflected in equation (3), and its set of constraints. The obvious reason is the stochastic parameter r_{ik}, which represents the newspaper rating for target groups. The reason why these parameters are stochastic is that these ratings represent the evaluation of the observed newspaper ratings. These ratings are calculated based on the number of copies printed, newspaper reputation and tradition and the assumed ratings for the position of advertisement placed in those newspapers. The method that is used to calculate these parameters is not in the focus of this paper, but what's important here is that these parameters are calculated monthly and adjusted on a six month period. For the purpose of the model, a case where uncertain parameters have a Gaussian distribution with expected value - μ and variance - σ is considered.

There are fourteen different target groups, which gives us a set of 14 stochastic constraints to be considered in total. This set of constraint is denoted as "soft" constraints, while all the other constraints are viewed as "hard" constraints. Since "hard" constraints must always be satisfied, they won't be considered in the optimization-simulation approach.

These target groups, and consequently the set of stochastic constraints, can be classified in four groups:

- Gender: the first two constraints define the minimum wanted rating achieved within male and female population,
- Age: there are six different age categories that are considered, and consequently the same number of constraints that define minimum wanted ratings within every age group,
- Geographic location: the model differentiates between three geographic locations where newspapers are sold, hence the minimum ratings that need to be achieved within the assigned geographic region are set,
- Education: three education levels are considered, and minimum ratings are assigned for them.

The set of 14 stochastic constraints become chance constraints with a predefined probability level of satisfaction in the following manner:

$$\left[\sum_i \sum_{k\in T} r_{ik} \sum_i \sum_{j\in P} x_{ij} \geq t_k \right] \geq p_i, i=1,...m$$

Decision maker sets the p_i level for every constraint.

Decision maker owns a chain of supermarkets and therefore wants to target a specific group through advertising. His focus and target group are women that are between 40 and 49 years old, from the geographical region G1 and have a university degree. This means that second, sixth, ninth and fourteenth constraint need to have the highest p_i level. Decision maker is willing to accept less than 0,5 percent risk that these constraints won't be satisfied, which means that p_i levels for these four constraints need to be higher than 99,5%. For all other constraints decision maker is willing to accept a 5% risk, namely, p_i levels are equal or higher than 95%. This is presented in the Table 1.

Table 1: Probability levels for soft constraints

Constraint	Gender		Age						Geographic region			Education		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
p_i (%)	≥95	**>99.5**	≥95	≥95	≥95	**>99.5**	≥95	≥95	**>99.5**	≥95	≥95	≥95	≥95	**>99.5**

Decision maker divided the set of soft constraints by selecting one constraint from each of the four groups of constraints, by accepting a minimal risk for these constraints not to be satisfied. In return, the decision maker demands at least 15% in currency spent less than if the robust approach was to be used on this model. So the tradeoff is described by accepting certain levels of risk in return for at least 15% better value of criterion function.

Having this in mind, the results of computational testing of proposed scenarios will be presented, as well as the general guidelines used for scenario generation.

Table 2: Computational results

Con	S1	p_i	S2	p_i	S3	p_i	S4	p_i	S5	p_i	S6	p_i
1	μ	50.61	μ-0.1 σ	57.15	μ-0.2σ	61.84	μ-0.3σ	68.81	μ-0.4σ	76.40	μ-0.5σ	81.51
2	μ	77.69	μ-0.1 σ	85.31	μ-0.2σ	88.64	μ-0.3σ	92.73	μ-0.4σ	93.36	μ-0.5σ	96.18
3	μ	96.48	μ	98.83	μ	97.30	μ	99.21	μ	98.18	μ	97.74
4	μ	55.49	μ-0.1 σ	62.22	μ-0.2σ	62.31	μ-0.3σ	65.95	μ-0.4σ	68.59	μ-0.5σ	72.00
5	μ	50.21	μ-0.1 σ	56.46	μ-0.2σ	61.89	μ-0.3σ	66.87	μ-0.4σ	72.08	μ-0.5σ	77.76
6	μ	84.16	μ-0.1 σ	89.44	μ-0.2σ	92.31	μ-0.3σ	96.02	μ-0.4σ	96.84	μ-0.5σ	98.08
7	μ	65.80	μ-0.1 σ	72.97	μ-0.2σ	77.33	μ-0.3σ	83.70	μ-0.4σ	87.75	μ-0.5σ	91.85
8	μ	50.60	μ-0.1 σ	56.59	μ-0.2σ	62.55	μ-0.3σ	68.76	μ-0.4σ	73.79	μ-0.5σ	80.38
9	μ	85.94	μ-0.1 σ	90.84	μ-0.2σ	93.58	μ-0.3σ	96.09	μ-0.4σ	97.27	μ-0.5σ	98.47
10	μ	64.57	μ-0.1 σ	70.60	μ-0.2σ	74.92	μ-0.3σ	82.51	μ-0.4σ	86.10	μ-0.5σ	90.20
11	μ	55.41	μ-0.1 σ	62.91	μ-0.2σ	66.62	μ-0.3σ	74.00	μ-0.4σ	78.43	μ-0.5σ	85.03
12	μ	99.70	μ	99.93	μ	99.94	μ	99.98	μ	99.99	μ	100
13	μ	96.73	μ	98.58	μ	98.30	μ	99.52	μ	99.34	μ	99.53
14	μ	88.99	μ-0.1 σ	92.08	μ-0.2σ	93.15	μ-0.3σ	95.83	μ-0.4σ	96.62	μ-0.5σ	97.77
f(x)	22.355.928		22.507.346		22.666.504		22.822.944		23.001.124		23.202.696	

Table 3: Computational results

Con	S7	p_i	S8	p_i	S9	p_i	S10	p_i	S11	p_i	Srob	p_i
1	μ-0.6σ	89.23	μ-0.7 σ	88.96	μ-0.8σ	94.32	μ-0.9σ	96.58	μ-0.9σ	98.64	μ-3σ	100
2	μ-0.6σ	97.24	μ-0.7 σ	99.33	μ-0.8σ	99.00	μ-0.9σ	99.50	μ-0.9σ	99.81	μ-3σ	100
3	μ	99.21	μ	99.61	μ	98.22	μ	98.38	μ	99.94	μ-3σ	100
4	μ-0.6σ	76.61	μ-0.7 σ	78.48	μ-0.8σ	80.48	μ-0.9σ	82.14	μ-1.5σ	96.66	μ-3σ	100
5	μ-0.6σ	84.55	μ-0.7 σ	87.95	μ-0.8σ	90.79	μ-0.9σ	94.31	μ-1σ	97.72	μ-3σ	100
6	μ-0.5σ	99.03	μ-0.5 σ	99.69	μ-0.5σ	99.85	μ-0.5σ	99.88	μ-0.5σ	99.90	μ-3σ	100
7	μ-0.5σ	95.14	μ-0.5 σ	97.83	μ-0.5σ	98.16	μ-0.5σ	99.02	μ-0.5σ	99.42	μ-3σ	100
8	μ-0.6σ	85.39	μ-0.7 σ	90.57	μ-0.8σ	93.23	μ-0.9σ	96.27	μ-0.9σ	96.21	μ-3σ	100
9	μ-0.6σ	99.17	μ-0.7 σ	99.62	μ-0.8σ	99.63	μ-0.9σ	99.85	μ-0.9σ	99.95	μ-3σ	100
10	μ-0.6σ	94.40	μ-0.6 σ	97.22	μ-0.6σ	97.87	μ-0.6σ	98.98	μ-0.6σ	99.09	μ-3σ	100
11	μ-0.6σ	89.81	μ-0.7 σ	93.79	μ-0.8σ	95.02	μ-0.8σ	97.22	μ-0.8σ	98.81	μ-3σ	100
12	μ	100	μ	100	μ	100	μ	100	μ	100	μ-3σ	100
13	μ	99.86	μ	99.92	μ	99.84	μ	99.91	μ	99.99	μ-3σ	100
14	μ-0.6σ	98.92	μ-0.7 σ	99.36	μ-0.7 σ	99.39	μ-0.7σ	99.69	μ-0.7σ	99.85	μ-3σ	100
f(x)	23.397.780		23.575.284		23.774.668		23.986.632		24.261.686		29.737.023	

In the two tables above, Table 2 and Table 3, the computational results of our scenario testing are presented. Scenario 1 and robust scenario are two border cases, and scenarios are generated between these two cases. In the first column, there is an indication to what the new deterministic equivalent is set to, and the following column presents the probability of satisfying the chance constraints of the scenario using the simulation approach described earlier. Each scenario is run through 10.000 simulations and appropriate probabilities are calculated and presented in the table. Value of the criterion function is presented accordingly for every scenario. Shaded cells indicate that there were changes made to the scenario for assigned constraint, relative to the previous scenario, meaning every change in creating a new scenario is marked in this fashion. This shows the approach, or heuristic, used to obtain wanted probabilities.

Now, a few words of the heuristic used. Starting from the expected values as the border case, deterministic realizations of the stochastic parameters are slowly moving towards a robust scenario that provides the highest probability of satisfying the constraints. However, three constraints were already satisfied with the probability over 95%, so it is decided not to change these stochastic values of parameter r_{ik}. Other constraints were not satisfying so scenarios were created towards the robust case by reducing the expected value by 0,1 σ in each scenario, keeping an eye on the p_i levels.

The basic presumption was that there is a strong positive correlation between constraints within their respective groups. Namely, in the set of constraints annotating the age a positive correlation between them was hypothesized. In terms of generating scenarios, this means that by satisfying one constraint of the group, the p_i levels of all the other constraints in that group will also be increased. Of course, it is assumed that these correlations are stronger between constraints that denote similar ages, like the age of 30-39 and the 40-49 years, than when there is a large age difference, like 12-19 and older than 66 years.

For the set of constraints that denote geographical regions, the same presumption is applied, as well as for the education. The only difference is on the set of constraints denoting gender. It is also assumed that there is a positive correlation between male and female population, but on a much lower level than in the other three set of constraints. This is to be expected considering different interests in newspapers for male and female population.

What this hypothesis actually means when generating a new scenario is that it won't be necessary to create a scenario that is getting closer to a robust one and one can still expect a certain increase in probability levels for a constraint if we have already decreased the value of a stochastic parameter in a constraint that is within the group of interest. For example, let's look at the constraints six and seven in scenarios S6 through S11. Stochastic parameter r_{ik} for these two constraints was set to μ-0.5σ in the scenario S6. Probability levels are 98,08% and 91,85% respectively. Our goal is to achieve probability level greater than 99.5%, and equal or greater than 95%. Yet, the value of stochastic parameters was kept the same, μ-0.5σ, all the way to the last scenario S11, and a steady increase in probability levels through every scenario afterwards is observed. This confirms the hypothesis of positive correlation within groups of constraints. The same pattern is used for other constraints, so the wanted probabilities in the last scenario were achieved.

The other very important advantage of this heuristic is that by keeping scenarios as far away as possible from the robust scenario, a better value of the criterion function is been generated. By applying this heuristic, both of the prerequisites for a good scenario are achieved: high probability levels for constraint satisfaction, and a better value of criterion function. Even though these two goals may seem opposed to each other, meaning that higher probability levels of satisfying constraints translates into an unfavorable value of a criterion function, the model still managed to achieve them both by applying the proposed heuristics and an iterative optimization-simulation approach.

Figure 2 shows the graphical results of the computational testing of scenarios:

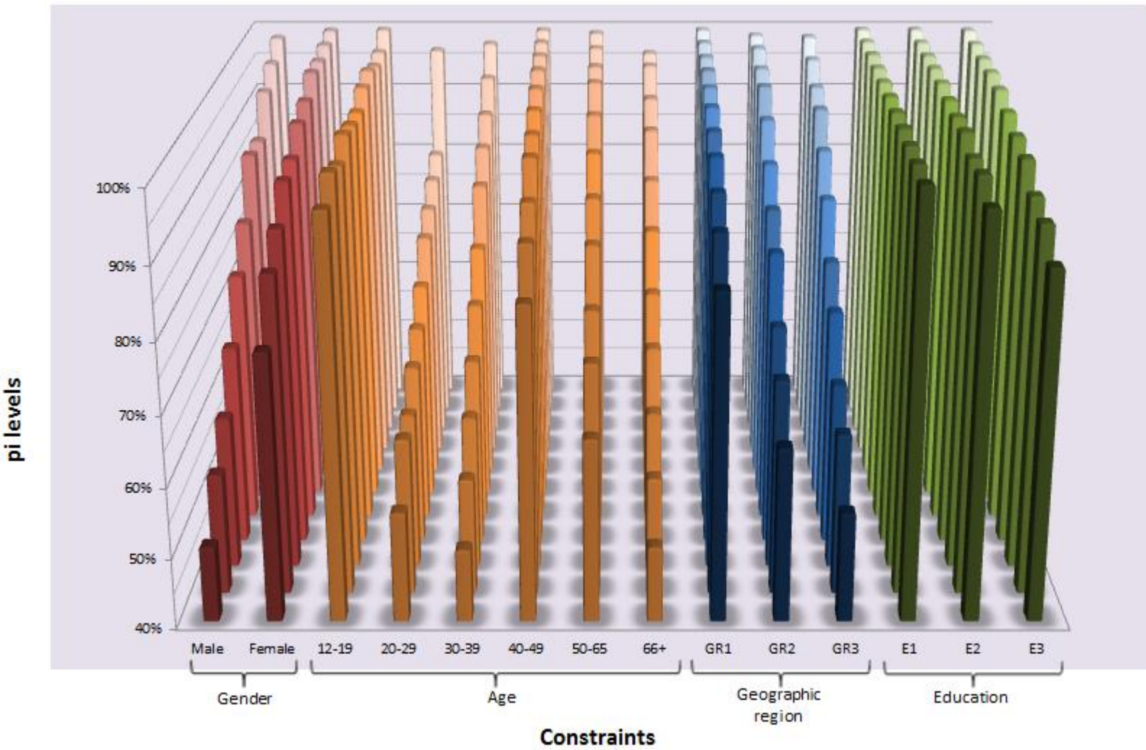

Figure 2: Graphical representation of computational results

Each group of constraints has its own color, and there are total of eleven scenarios presented here, all but the robust one. This chart shows how p_i levels increase with every new scenario.

6. CONCLUSION

In this paper, an original approach for tackling uncertainty in a model was put forward and general guidelines of how to use an optimization-simulation approach to stochastic linear programming in practice was given. Combining chance constraint approach and a robust approach to a problem with stochastic parameters is the foundation of the framework. In addition, using the power of simulation to check probabilities of chance constraints is the backbone of the approach. Advertisement placement model, which is by its nature a stochastic problem, is used to show how the optimization-simulation model works in practice. By using the proposed heuristics, one is able to generate valid scenarios to be optimized and checked through simulation. Understanding a specific problem is of essence when generating scenarios and applying the proposed framework. Incorporating the preferences of the decision maker is also an important part of the model.

Numerical and graphical results of the proposed approach on an advertisement placement model are also provided. The approach is intuitive and easy to understand and apply to real life problems.

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RATIONALIZATION OF STORAGE COSTS BY APPLICATION OF MODIFIED SMED METHOD

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Abstract: *In modern business, the flexibility of production, i.e. the possibility of production of a large number of various products, with minimal storage costs of the material, is one of key factors of the success. This is mostly important in automotive industry where the production is based on Just in Time production and every loss of capacity due to frequent and insufficiently fast changes of tools/forms can easily cause failure to fulfil the daily plan of production. This can caused very big effect, stopping of the production line of the customer. This paper reviews the modified SMED (Single Minutes of Exchange of Die) method by whose application the flexibility and competitiveness of some company can be significantly improved by reducing of the operating costs i.e. for the same spent time it's possible to change production program more time, give us possibility to reduce batch size and space needed to store the goods. This modified SMED method is different from others because for the process of data analyze is used statistical method, t-test, which caused big cost reduction for testing and time needed to performed it. Except that, in the paper is present the significant correlation between results of SMED and way of production planning, with the goal to reduce and stabilize the stock. Multiple benefits of using of SMED method is reflected in the fact that in addition to saving storage space, also getting the flexibility of the production system which enables faster response and adaptation to daily customer's requests.*

Keywords: *SMED method, stock reduction, automotive, flexibility, batch size*

1. INTRODUCTION

In circumstances of adapting to changing requirements of users, one of the problems in the production is appropriate preparation of the machines, and/or preparatory - final time. The duration of the preparation of the machine for the second operation is very frequently very long, which in small quantities in the series, and that is the case when we adapt to changing requirements of users, burdens the production unit by additional time and costs. In an effort to enable as greater adaptability as possible within the observed company, the significant attention is devoted to rationalization of activities within the preparatory - final complex of actions with the aim of their shortening.

The basic idea in realizing the shortening of preparatory - final time is in implementing of all necessary actions while the machine is running, so that the machine would stop only while performing of those activities which cannot be performed while the machine is in motion. Likewise, the duration of all activities on the machine while it is not in motion should be shortened by all available methods and rationalization techniques. Separation of these activities is a key and starting basis for all further efforts, because thus the research is expediently directed in the field of those activities that determine duration of preparatory - final activities.

Globalization of the market has created the need for the production in small batches, by which the increase in the number of machine setting and equipment is conditioned, as well as the reducing of production time of a batch. For these reasons, it is necessary that the replacement of production be faster so that the flexibility does not influence on the speed of the response to a request (Mcintosh et al, 2007).

Goubergen and Landeghem (Goubergen and Landeghem, 2002) have divided various reasons into three main groups:

1. Flexibility : Due to a large number of various products and reduction in their quantities, the company must be able to respond quickly to customer's demand. That is, if it is necessary to produce in small batches, it is of great importance to be able to perform the change of tools in the shortest possible time,
2. Lack of capacity: Every loss, especially in these conditions, even of one minute while changing the tool is a huge loss. Every reduction of time of tool change is directly reflected on the increase in capacity,

3. Reduction in costs: cost of production and storage is in direct conjunction with the machine performances,

According to Haron and Peterson (Harmon & Peterson, 1991) reduction in time necessary for setting is important for three reasons:

- Great expense during a complicated change of tools and setting of the process causes the increase in production series, by which the investing in stocks,
- Rapid and simple technique for tool change reduces the possibility of errors during the equipment setting,
- Reduction and simplification of setting increase the operating time of the machine.

Also, one of key factors for improvement of the process of production change, and it has not been mentioned in any of the above-mentioned analyses, is the production plan. Its importance is great because of adequate and timely preparation of the operators that work on the change, and so that the process be adequately prepared and all external operations done in accordance with the standard. One of the key external operations, for which the exact time of tool change is very important, is pre-heating of tools for the sake of reducing of the time of waiting for warm-up while the tool is in the machine.

Frequent changes of product range on request of the market cause significant percentage of preparatory-final time in the machine running and cannot be eliminated but it only can be minimized by application of appropriate methods.

Since SMED method that Shigeo Shingo has improved is one of the basic, and the others are based on it, in the following, we will deal with its analysis and the results of its application, i.e. its influence on the factors which Harmon and Peterson have singled out, primarily on the inventory levels.

Shingo defends the idea that SMED method is composed of various techniques by which the setting is possibly reduced to less than 10 minutes, or that even the number of necessary minutes for change be reduced to a single digit (Shingo, 1989).

2. THE PREPARATION OF THE EXPERIMENT

The process of tool change is carried out in five steps which are conditioned by one another:

- Stopping of the machine
- Removing of tool
- Inserting of new tool
- Tool change
- Starting of the machine

and duration of tool change counts from the last good part of the last batch to the first good part of the next batch (figure 1).

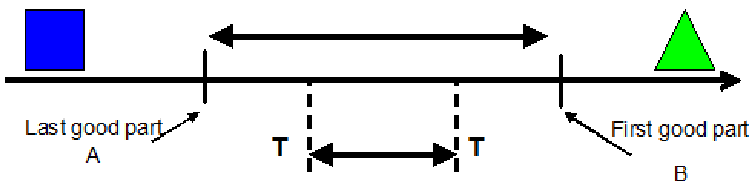

Figure 1: Diagram of the time of tool change (Changeover of Production and Lot sizing, Toll GPE 0097, 11.2010, Mecaplast, Monaco)

The focus in this paper will be on the analysis of the activities that is necessary to be made during one SMED, and their redistribution with the aim that the number of internal operations be as small as possible.
For this purpose it is not necessary to analyse every machine individually, because it has been established by the analysis that the schedule of steps that should be performed on the machines is the same, only the duration of performance of certain steps differs, which can statistically be proved. (Ana Sofia Alves et al, 2009).

For the purpose of this proving we will use t-test, known as "Student's" t-test. There are 3 types of t-test and these are:

- One sample t-test that is commonly used for the comparison of the mean value of one group of data with target mean value,
- Two sample t-test when the mean value of one group of data should be compared with the mean value of the other,
- Paired t-test when we want to compare the values before and after a particular treatment.

Before the application of t-test it is necessary to determine the normality of data of the population of samples with which it is handled. If the distribution of population values of samples is normal, either F-test (if σ levels are compared) or 2 samples t-test (if the mean population values are compared) are used for the comparison. If the distribution of data does not give a normal distribution, the test that is used for the comparison is Levene's test.

The results of data normality test during the tool change on the machines of small tonnage (200t - 550t), and for the data for the machines of large tonnage (550t - 1300t) are represented in the following diagrams (figure 4). As the distribution is normal in both cases, P>0.05, one could continue with the application of some of t-tests which have aimed at proving that two groups of results of 30 samples per each for the machine of 200t and for the machine of 500t, are statistically the same.

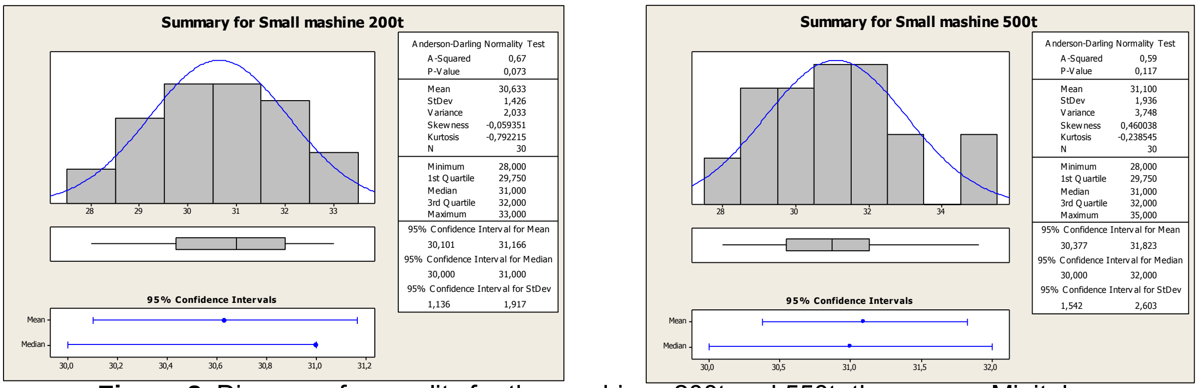

Figure 2: Diagram of normality for the machines 200t and 550t, the source: Minitab

When it comes to the two data populations, and as the mean value of those populations is compared, 2-t test has been chosen as relevant for proving the statistical equality of the two populations.

2 sample t-test consists of the confirmation of null hypothesis (equation 1) and alternative hypothesis (equation 2):

$$H_0 = \mu_1 - \mu_2 = 0 \tag{1}$$

$$\mathrm{H}_1 = \mu_1 - \mu_2 \neq 0 \tag{2}$$

By the confirmation of null hypothesis, if the value is P > α=0.05, where α represents the coefficient of risk (significance level) and its value is usually 5% or 0.05, it is confirmed that the mean values of populations are equal, i.e. that there is no difference between the populations. Otherwise, the null hypothesis is rejected and the alternative hypothesis is accepted. The value P, as well as the other values can be seen in the statement of Minitab, software for statistical data processing (figure 3).

Two-Sample T-Test and CI: Small mashine 200t; Small mashine 500t

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Two-sample T for Small mashine 200t vs Small mashine 500t

                    N   Mean  StDev  SE Mean
Small mashine 200t  30  30,63   1,43     0,26
Small mashine 500t  30  31,10   1,94     0,35


Difference = mu (Small mashine 200t) - mu (Small mashine 500t)
Estimate for difference:  -0,467
95% CI for difference:  (-1,347; 0,414)
T-Test of difference = 0 (vs not =): T-Value = -1,06  P-Value = 0,293  DF = 53
```

Figure 3: The statement of the results of 2 Sample t-Tests, Minitab

where N represents the number of samples per population, Mean - the mean value for the population, StDev- standard deviation, DF - number of degrees of freedom.
As the value P = 0.293> of the given α=0.05, it means that the null hypothesis is accepted, by which it is confirmed that in the further review, the conclusions that have been drawn for one machine refer to all machines from this group. The identical conclusion has been drawn also for the group of machines over 500t, by which the range of research and number of experiments have significantly reduced, i.e. the number of observations has reduced from 11 to only 2 representative samples from 2 populations of machines. The results of this test have significantly influenced on the reduction in the costs of further analysis.

3. THE PRACTICAL APPLICATION SMED METHOD AND ITS EFFECTS

The method of observation, collection and processing of data in the example of group of machines from 200t to 500t will be shown in the following, with the proviso that at the end the results from both groups of machines and common conclusions will be shown.

Observation, collection, analysis and control have been done on the basis of Shingo's division and distribution of operations (figure 4).

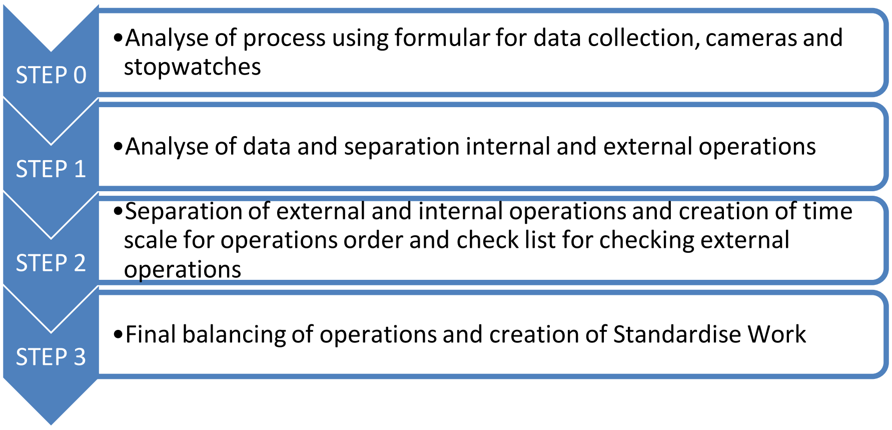

Figure 4: Diagram review of Shingo's method

Step 0 (Internal and External setup): In this step we cannot distinguish what the internal operations are and what the external operations are. It is necessary here to perform the analysis of existing production process with the presence of the operators that are normally engaged in tool change and process setting. It is necessary to analyse the time of every single activity, and by recommendation of Shingo, during this analysis one should use stopwatch, as well as make a movie during the production change.

Observation has been done by synchronous monitoring of two operators, wherein their every activity, its duration, the manner of operator's movement and distance that he has going while performing every single activity have been recorded in the form. As a result, at the end of this form one can see the total duration of all activities, as well as the total distance that each of the operators have gone.

Step 1 (Separation of internal and external operations): In this step it is necessary to separate internal and external operations by the analysis. According to Shingo, this step is extremely important in the implementation of SMED. He claims that, in this step, the total time of setting can be reduced 30% to 50%.

By the analysis of comparative time diagram of operations (figure 5) is the most important in this step, where the duration of every operation has been presented by the line whose length indicates the duration of the operation. Here, in addition to the duration, it can also be seen which activities are mutually ovelapping, or where exists certain waiting at interdependent operations. Based on this and the next diagram (figure 10) it can also be concluded which operations can be performed before stopping of the machine.

Step 2 (Transforming of internal into external operations): in this step it is the most important that the separated internal operations transform into external, i.e. to perform them while the machine still operates.
This involves the activities such as: preparation, check and preheating of tool before the starting of the change itself, i.e. stopping of the machine. Also, check and change of material can be done as external operation. The important precondition for correct performing of the operation of tool preheating as an external operation is the existence of precise plan of production. With precise plan, i.e. precisely defined time of completion of the previous batch, the operator that performs the preparation of tool can start the

preheating of tool on time so that it can be completed by the time when the tool has to be placed in the machine. None of the previous authors has taken this detail into their examination as an important factor in the duration of change. In the case that the tool has not been set on the counter for preheating on time, it happens that the tool, which is insufficiently heated, is inserted into the machine, whereby the time of its heating for the start of production in the machine itself is extended, which directly increases the time of change.

In the checklist of external operations there are the following items that are necessary to be checked before the stopping of the machine: raw material – whether it is appropriate, on the marked place and prepared for production according to the standard, the presence and state of hand tool, presence and state of peripheral equipment for production, the state of connectors and the state of preheating of tool that is prepared for change, documentation on the workplace etc.
By the examination of comparative diagram (figure 6), it can be concluded that the time required for performing the work of the first and second operator is not balanced, and that one should check the possibility of switching of some of the operations, which is performed one of the operators, to the other operator and vice versa, and in order to equate their time and to reduce the total time.

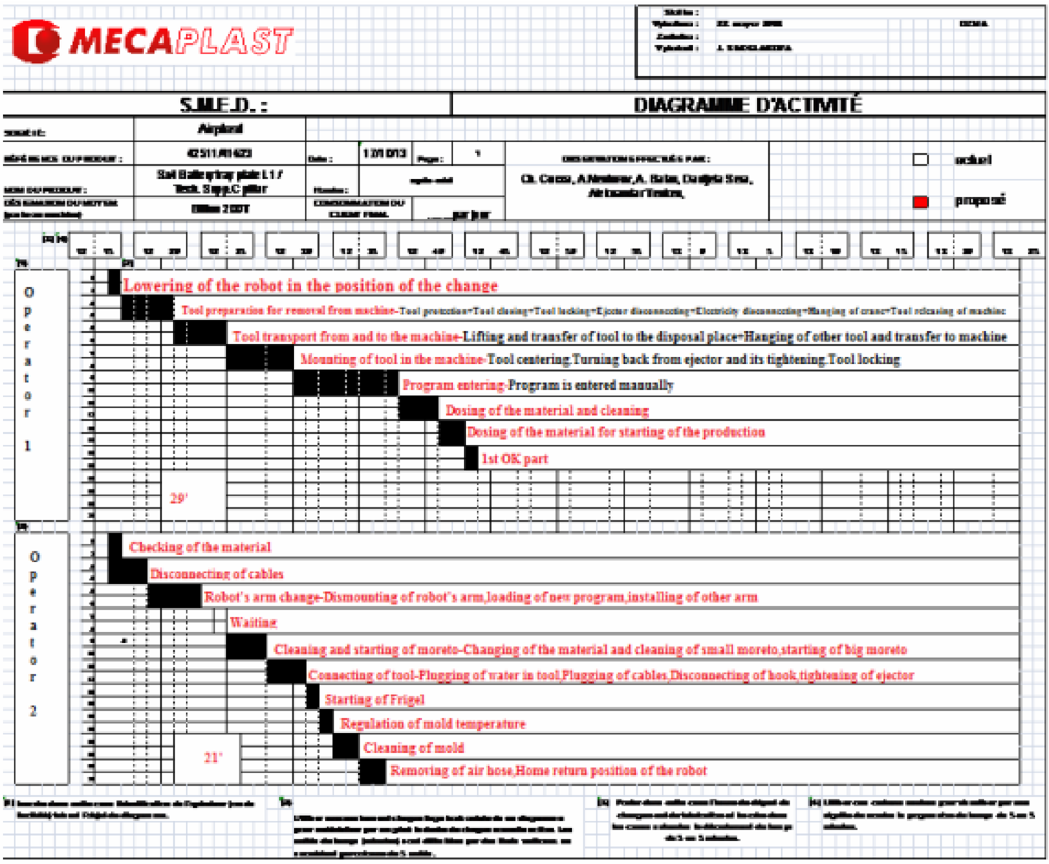

Figure 5: The diagram man - machine, the comparative display of the schedule and duration of operations (Changeover of Production and Lot sizing, Toll GPE 0097, 11.2010, Mecaplast, Monaco

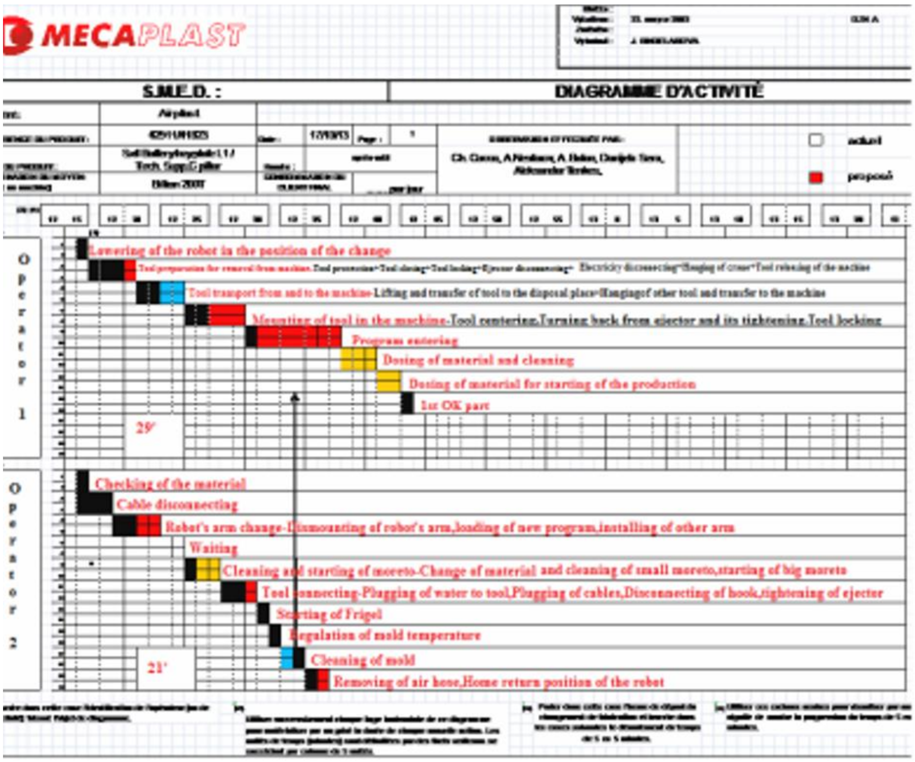

Figure 6: The diagram man - machine, separate external operations and the operations that can be eliminated (Changeover of Production and Lot sizing, Toll GPE 0097, 11.2010, Mecaplast, Monaco

The operations highlighted in yellow (figure 6) are the operations that refer to the material change and cleaning of the dryer of material, and they have been identified as the operations before the machine stops, i.e. they can become the external operations, and they have been placed in the checklist (figure 7). This move would save 5 minutes of the time of the operator 1., and 2 minutes of the operator 2.

As it can be seen in diagram (figure 7), by the application of the first two steps (0,1,2) of Shingo's methodology, the time of the tool change at the operator 1 has been reduced for 62%, i.e. from initial 29 minutes the time of change has reduced to 11 minutes, while at the operator 2 that percentage is 38% (from 21 minutes we have reduced to 13 minutes).

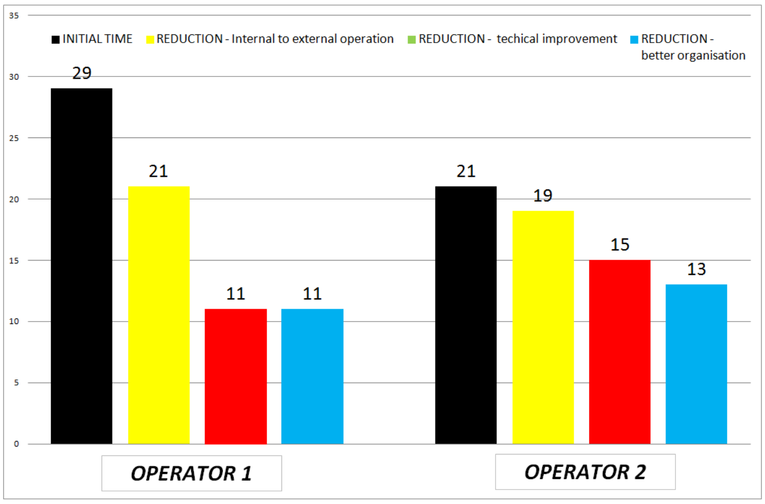

Figure 7: The comparative display of the improvement of SMED by the application of Shingo methodology

Step 3 (final balancing of operations) - By the application of this third step, the final balancing of operations are performed, as well as final reducing and eliminating of unnecessary activities. As it is shown, our 2 operators do not have balanced time of performing of their operations, i.e. the operator 1 finishes his work for 2 minutes earlier than the operator 2. As those 2 minutes, during which the operator 1 does not perform any activity, influence on the extension of total time of tool change, the assignment is to find appropriate activity that lasts 1 minute which performs the operator 2, and shift it to the list of activities of the first operator.

Cleaning of mold, one of last operations of the second operator, has been identified as a potential activity for assigning to the first operator.

After final balancing, both operators have the same final time of 11 minutes, and by which the total time of change has been reduced for yet additional 7,7 %.

Final display of the schedule of the operations is shown in diagram of operations (figure 8).

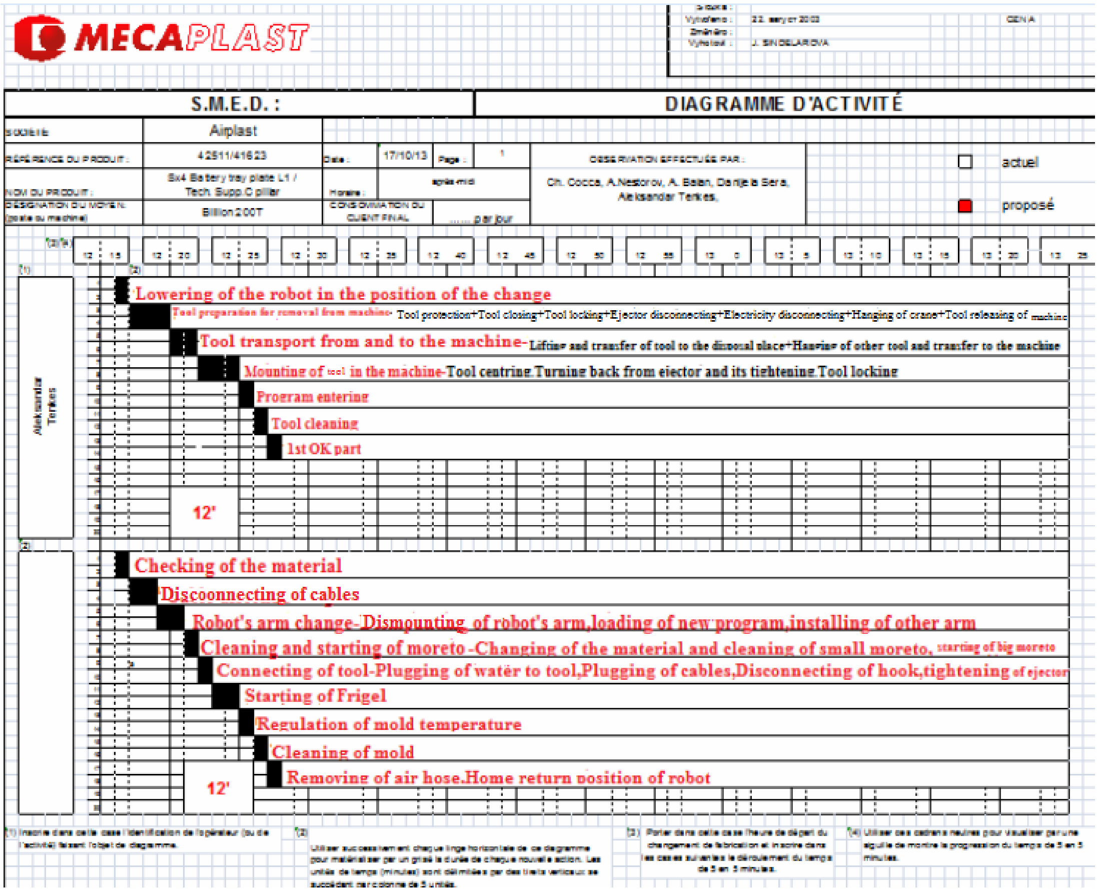

Figure 8: Diagram man-machine, the final display of the schedule of the operations (Changeover of Production and Lot sizing, Toll GPE 0097, 11.2010, Mecaplast, Monaco

The final result of the application of SMED method to both groups of machines is presented in table (table 2) as follows.

Table 1: Comparative display of reducing of tool change by *the application of SMED method*

Group	*Initial time average*	*External set-up operation*	*Improvement %*	*Techical improvement*	*Improvement %*	*Better organisation*	*Improvement %*	*Final balance of operations*	*Improvement %*
Small mashines (200t - 550t)	30	21	***30***	16	***47***	13	***57***	12	***60***
Big mashines (550t - 1300t)	45	35	***22***	32	***29***	30	***33***	27	***40***

As it can be seen from the presented table, by the application of SMED method to these two groups of machines, total time that is necessary for tool replacement has reduced for 60% for the group of small machines, and/or 40% for the group of the machines over 550t.

Reducing of total time of change has influenced on:

- reducing of storage costs,
- increasing of production flexibility,
- increasing of the capacity of production equipment.

Quantity of goods that is in stock depends on several factors, and one of the most important is the size of the production batch. As the size of the production batch is directly related to the time of tool change, hence the indirect connection of the time of tool change to the quantity of stored goods.

For calculation of the size of batch, as well as for the quantity of stored product (semi-product / final product) KANBAN calculation has been used, and one of key factors in that calculation is the time of tool change, as well as the number of replacements during the day.

During the calculation of the batch size, the influential factors that are taken into consideration are:
Available time of the machine for production during the day, cyclical time of action, the number of tool changes which it is possible to be performed on the machine on which the product that is the subject of the analysis is produced, the duration of tool change.
The batch size (LE) is one of the factors in the calculation of the time required for renewal of one card - lead time (TA), minimum stock that can endure the fluctuation - pool stock (SM), the values of Kanban card= 36 parts (Vk, 1Vk = 1 transport trolley = 36 parts), the request of the buyer per day (CMJ), which is presented by the equation (equation 3):

$$N_k = \frac{\left((\mathrm{TA+SM})\mathrm{xCMJ}\right)+\mathrm{LE}}{V_k} \quad (3)$$

In the example of one referential number, the number of required Kanban cards is calculated in the following way:

TA = 2 h, SM = 8 h, CMJ = 600 pieces/day = 25 pieces/h, LE = 450 pieces, Vk = 36 pieces

$$N_k = \frac{\left(((2\mathrm{h}+8\mathrm{h})\mathrm{x}25\frac{\mathrm{kom}}{\mathrm{h}}\right)+450}{36\ kom} = 20\ cards \quad (4)$$

Using of the results of the equation 3, i.e. by multiplying the maximum number of Kanban cards required for every single product with the surface required for placing of one kanban unit, one obtains required size of space for placing of every single reference. Of course, in this one should also take care of the information on the method of packing of kanban units in the warehouse (possibility of packing in more), which can significantly influence on the final result.

Speeding up the process of tool change influences on reducing of production batch which also entails reducing of required number of Kanban units in every moment. Table (table 2) shows the relation of old and new value of stock by groups, preoccupied space as well as released capacity for both groups of machines after the application of SMED method in the production plant of the company "Mecaplast".

Table 2: Display of benefit of SMED method application

Group	Old stock value **€**	Old stock occupation **m2**	New stock value **€**	New stock occupation **m2**	Free capacity **h/day**
Small mashines (200t - 550t)	***5760***	***85,4***	***2220***	***26,6***	**2,7**
Big mashines (550t - 1300t)	***98880***	***324***	***47064***	***104***	**4,8**

Total freed capital by this action is 55,300 € by reducing of stored quantity, 280 m2 of space that has been used for storage, as well as 2,7h and/or 4,8h of released capacity in both groups of machines per day.

As the part of the production plant is used for the storage of semi-products, it can be concluded that by optimization, i.e. by reducing of preparatory time on all machines, the space that can be used for placing of new production units would be significantly unloaded, and without additional expansion of the existing facility, i.e. additional investments.

4. CONCLUSION

On a practical example in the paper it is shown how the application of Shingo's SMED method can influence very efficiently on very important factors, identified by many authors from the beginning, with a large impact on operating of one system. Some of those factors are the costs of storage, the capacity of equipment, flexibility of production etc.

The importance of this paper also represents the display of successful combining of SMED method with other methods, primarily with statistical analysis, and in order to conduct the experiment as efficiently and economically as possible. As it is shown in the paper, after the statistical confirmation that the group of 11 machines for vertical injection is possible to be divided into only 2 groups, the experiment has been conducted on 2 representative samples, one representative from each of the two populations. The conclusions that have been obtained based on the analysis of the results of representatives are implicated on the entire group, whereby the total number of experiments (11) has been reduced to only 2, which has significantly reduced the duration and cost of the complete analysis.

The difference of application of SMED method shown in this paper and other described SMED methods is that the production plan has been also considered here as an influential factor on the duration of change. It has been explained how imprecise and incompletely defined production plan can influence on the total extension of the time of tool change. In support of this, the way of calculation of Kanban system that has been used in the combination with SMED method is presented so that required needs for quantities, capacities and space be determined more rationally. Also, Kanban gives us the possibility of work without classical production plan with constant batch size, whereby the determination of the end of the production batch is ensured, and thereby of the beginning of the preparation of tool change. The result of that is more efficient SMED.

By the analysis of the results and by the implementation of SMED standard on all machines, the saving has been achieved of 55,000 € in freed goods and 200 m2 of storage space.
As the freed space is within production space, it could be used for placing of 4 new machines, whereby the potential investment in the expansion of the facility in the value of 200,000 € is avoided. This proves that the benefit of the application of SMED method is not insignificant.

The importance of this research is reflected in the fact that all tools that have been shown belong to LEAN philosophy that is increasingly current by the change in business climate in our country, primarily after the arrival of a large number of foreign companies. Owners and managers increasingly look for the concrete solutions and concrete and visible results.

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KEY PERFORMANCE INDICATORS AND PRICING STRATEGIES PLANNING IN RETAIL INDUSTRY

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Abstract: *Choosing and using key performance indicators is necessary for each part of the economy. Retail market is one of the most dynamic fields in economy, and choosing and analyzing the right indicators could be crucial for decision making. This paper should provide guidelines for choosing adequate key performance indicators in retail industry, but also give a brief overview on the different aspects of interpreting those indicators. Modern retail is mostly focused on two main indicators: Turnover and Gross margin, which are directly affecting profitability of retailers. Mentioned indicators could be analyzed more detailed which is of special meaning for lower levels of management. Turnover and Gross margin are indicators that are the basics for many other indicators – Market share, EBIT/EBITDA/EBITDAR, for vertical and horizontal financial analysis, etc. Based on that fact, there are many factors which are dictating the potential turnover and gross margin. One of the main factors are prices and prices strategies. In retail, there are two main pricing strategies: EDLP (Every Day Low Prices) and Hi-Lo (High-Low). Since turnover could be calculated as quantity multiplied with prices, pricing strategies are in position to define planned level of turnover and gross margin. Managing prices successfully gives a good platform for managing key indicators and decision making.*

Keywords*: retail, turnover, gross margin, key performance indicators, pricing strategies planning*

1. INTRODUCTION

The idea of this paper is to present which indicators are relevant and how to choose them, focusing on the retail industry as one of the biggest industries. Also the idea is to make a differentiation between performance indicators and key performance indicators. Key performance indicators (KPIs) could be defined as points on which companies should pay attention the most, and based on which, companies can make decisions. There is a slight difference between KPI and PI (performance indicator). Key indicators are those indicators, which could help management to make strong decisions that will directly affect (positively) on the business results. On the other hand, performance indicators can also affect business results, but without direct impact on business results (for example: tracking employees satisfaction cannot give exact information, did it increase or decrease EBIT[1]/EBITDA[2], etc.). Based on the different levels of top management, key indicators are mostly tracked, analyzed and controlled by every level of management.

The purpose of the paper is to perceive pricing strategies as one of the important parts of all retail strategies, considering other parts of business and to show their impact on some of the key performance indicators. There are several pricing strategies, but two of them are mostly used. More about pricing strategies can be seen in the point 3 of this paper.

The idea of this paper will be presented, considering theoretical frame of key performance indicators, then the development of the retail industry and the use of key performance industry in retail. Afterword, there will be more about pricing strategies and their effect on key indicators. Generally, this paper should present the link between key indicators and pricing strategies and the way they are used to concept.

2. KEY PEROFORMANCE INDICATORS AND THEIR USE IN MODERN BUSINESS

Key performance indicators (KPIs) could be defined as points on which companies should pay attention the most, and based on which, companies can make decisions. There is a slight difference between KPI and PI (performance indicator). Key indicators are those indicators, which could help management to make strong decisions that will directly affect (positively) on the business results. On the other hand, performance indicators can also affect business results, but without direct impact on business results (for example: tracking employees satisfaction cannot give exact information, did it increase or decrease business results, etc.).

[1] Earnings Before Interest and Taxes
[2] Earnings Before Interest, Taxes, Depresiation and Amortization

The starting point for choosing the right performance indicators is to make a list of indicators which are of interest for the board. Those indicators are mostly considered as key ones. Financial performance indicators are mostly used by the top management to manage the business. On the other hand, non-financial indicators are becoming important as much as financial indicators. A challenge is whether the KPIs currently presented to the board are those that allow them to assess progress against stated strategies, and when reported externally, allow readers to make a similar assessment.

Appropriate selection of indicators that will be used for measuring is of a greatest importance. Process organization of business is necessary to be constituted in order to realize such effective and efficient system or performance measuring via KPI. Process organization also implies customer orientation and necessary flexibility in nowadays condition of global competition (Velimirovic, 2010).

New business conditions where information is the most important resource impose new approaches in measuring performances of organizations, related to traditional performance measurement system which evolved just financial and accounting indicators. One of the newer approaches refer on measuring performances of organizations via KPI. KPI are financial and non- financial measures that organizations use to reveal how successful they were in accomplishing long lasting goals. In order to constitute effective system of performance measurement it is very important to have defined and standardized all processes within the organization (Velimirović D, 2010).

The overriding need is for the KPIs to be relevant to that particular company. Management should explain their choice in the context of the chosen strategies and objectives and provide sufficient detail on measurement methods to allow readers to make comparisons to other companies' choices where they want to (Price Water House Coopers, 2014, pp. 8-11).

However, it is the management's duty to suggest and make a portfolio of indicators which will be measured, tracked, analyzed and which will give a good basis for decision making. Considering business conditions, Kaplan and Norton recommended not to use more than 20 key performance indicators. Hope and Fraser suggested even less than 10 KPIs. Even though, the focus in this paper is on key performance indicators, performance indicators (PIs) and key result indicators (KRIs) are important as well. The 10/80/10 rule could be considered as a good proportion and segmentation of the number of tracked KPI/PI/KRIs[3]. It suggests using about 10 KRIs, up to 80 PIs, and 10 KPIs in an organization. For many organizations 80 PIs will at first appear totally inadequate.

Table 1: 10/80/10 Rule
Source: Permanter D, (2007) *Key performance indicators - Developing, Implementing and Using Winning KPIs,* p. 9

TYPE OF INDICATORS	GUIDANCE
Key result indicators (10)	Give information how have organization done in perspective
Performance indicators (80)	Give information and guidance what to do
Key performance indicators (80)	Give information what to do to increase performance dramatically

Many organizations will probably find tracking only 10 KPIs restrictive and may wish to increase the number of KPIs. That could be acceptable and rational if organization is made up from businesses from different sectors, in which case the 10/80/10 rule can apply to each diverse business. In that point, it is normal to increase KPI rollout (Parmanter D, 2007, pp. 8 - 10).

Retail is one of the most important parts of the global economy. Modification of retail from traditional retail to modern retail (online shopping/shopping with entertainment, etc.) has certainly changed KPIs that are tracked (from simple tracking of turnover, retail is now tracking some more advanced KPIs which will be considered in this paper). According to that fact, it is important to perceive the development of retail industry as well.

3. DEVELOPMENT OF THE RETAIL INDUSTRY AND INNOVATION AS THE INCENTIVE FOR TURNOVER

The retail industry has undergone drastic changes in the 80s of the last century. "Modern trade "and the development of large retail chains which could compete with their low-cost products have made a new standard of retailing. It all started with the sale of goods at predetermined locations where buyers would buy the goods

[3] KRIs (Key Results Indicators) mostly cover a longer period of time than KPIs. They are reviewed on monthly/quarterly cycles (not on a daily/weekly basis as KPIs). Separating KRIs from other measures has a profound impact on reporting, resulting in a separation of performance measures into those impacting governance and those impacting management.

they want at a given time and in a given location. Today, retail centers, beside grocery stores, include many specialized sales facilities - bookstores, boutiques and the others (which could be presented as shop-in-shop[4]).

During the 1980s and 1990s, retail industry started changing to modern-retail, under the influence of new technologies. Mass usage of bar codes and development of the internet has reconstructed the traditional ways of retail. Thus, the primary focus during the 80s and 90s was on inventory management, tracking billing and payment methods. Nowadays, CRM is even more changing the retail industry in the terms of specialized offers and connecting the customers with retailers (Dunković D, 2010).

During the 20th century, loyalty programs created a new sphere of retailing – making special offers and analyzing the needs of a customer in order to keep the existing customers, but also to attract the new ones and increase total turnover. Retailers who are leaders in innovation are moving faster in the terms of earning more, attracting more customers and having higher rates of growth. In the table 1, there is a data of top grocery retailers from 2013th year, according to the net sales.

Walmart is the world's biggest retail chain, considering net sales of 467 billion $, earned in 28 countries worldwide. Such as in every other industry, leading retail chains are dictating the tempo and trend of retail. In the previous past years, there is a trend of quick buying, in the lack of time.

However, online retail is getting more popular, and this kind of retail gives a lot to both – customer and a retailer. To a customer it gives more time to spend free, with the delivery on the wanted address, and to a retailer it gives better chances to operate more successfully with supplies.

Table 2: World greatest grocery retail chains
Source: Deloite, Report 2015: *Global Power of Retailing*, pp. 11-16

Rang	Name	Net sales in mil $ (2013.)	No. of countries	Country of orgin	2008-2013 average rate of growth
1	Walmart Stores Ltd.	476.294	28	America	3,30%
3	Carrefour S.A.	98.688	9	France	7,70%
5	Tesco PLC	98.631	18	Great Britain	2,90%
7	Metro Ag	86.393	32	Germany	-0,90%
14	Groupe Auchan S.A.	62.444	13	France	4,00%
17	Aeon Co. Ltd.	57.968	10	Japan	3,90%
24	Ahold N.V.	43.321	7	Netherlands	4,90%
33	Delhaize Group S.A.	28.037	9	Belgium	2,10%
38	Migros	25.010	3	Switzerland	5,40%
42	Marcadona S.A.	23.954	1	Spain	4,80%
63	Coop Italia	15.211	1	Italy	-0,20%
64	Meijer Inc.	15.000	1	America	1,80%
71	S Group	13,233	5	Finland	6,20%
73	Whole Food Market Inc.	12.917	3	America	10,20%
78	China Resources Enterprise, Limited	12,258	5	China (Hong Kong)	22,40%
222	Agrokor d.d.	4,011	3	Croatia	/
226	Axfood AB	3,989	1	Sweden	2,40%
234	Heiwado Co, Ltd.	3,863	2	Japan	-0,40%
241	SMU S.A.	3,823	2	Chile	29,80%
250	Overwaitea Food Group	3,700	1	Canada	6,50%

As the retail industry is considered one of the most dynamic and fastest growing industries, innovation are essential for the survival and development of the market. Innovation in this industry does not necessarily refer

[4] Shop in shop stores are stores specialized for selling a specific group of goods within bigger shopping markets. For example, in Roda Megamarkets, there are specialized shop-in-shop objects for selling equipment of Basketball Assosiation of Serbia.

only to the technology, a new billing system, the system of price reductions, but can also refer to innovations in marketing campaigns, which is the most common example of innovation in this industry.

So, speaking of innovation, it is important in the terms of overall growth and growth of the turnover of a retailer. Generally, there are two main types of innovation in retail: operational and strategic innovation. Operational innovation is related to operational improvements, while strategic innovation is related to radical changes within the retail network. The purpose of innovation in the retail network is approximation of consumer needs, with critical requirements in terms of quality and price. From the standpoint of the company, the time of implementing some innovation is a key factor, due the dynamic of the retail market.

4. KEY PERFORMANCE INDICATORS IN RETAIL INDUSTRY

There are several indicators, which could be considered as key indicators in retail. One of the most basic key performance indicators is total turnover. Turnover in retail could be defined as the quantity of goods sold to customers, or as a total value of those goods. So, it could be presented as both, quantity and value.

Turnover is an input for many other indicators, such as:

- Market share,
- Margins of cost,
- Result (EBIT/EBITDA/EBITDAR),
- Turnover per (m^2, employee),
- etc.

Turnover as itself is the basics for calculating other indicators. Every position in income statement start with total turnover. Table 2 (below) shows the structure of P&L statement (*Income statement*), with total turnover as starting position.

Table 3: Structure of income statement in retail with total turnover as the starting position

TOTAL TURNOVER
-
VALUE ADDED TAX
SALES REVENUES – DISCOUNTS = NET SALES
-
COGS (COST OF GOODS SOLD)
GROSS MARGIN
-
OTHER INCOMES (RENT, REVENUES FROM DISCOUNTS AND OTHER IN-STORE ACTIVITIES WITH PARTNERS, OTHER INCOMES)
TOTAL NET REVENUES
-
TOTAL COSTS
-
OTHER COSTS
OPERATING RESULT (EBITDA - EARNINGS BEFORE INTEREST, TAX, AMORTIZATION AND DEPRECIATION**)**
+
FINANCIAL REVENUES
-
FINANCIAL COSTS
EBIT (EARNINGS BEFORE INTEREST AND TAX)
EBITDAR (EARNINGS BEFORE INTEREST, TAX, AMORTIZATION, DEPRECIATION AND RENT)

Both, turnover and gross margin are contributing to the profitability of a company. However, turnover with low margin rates is not enough for a sustainable profitability. On the picture bellow (Figure 2), it is explained how turnover and gross margin are connected.

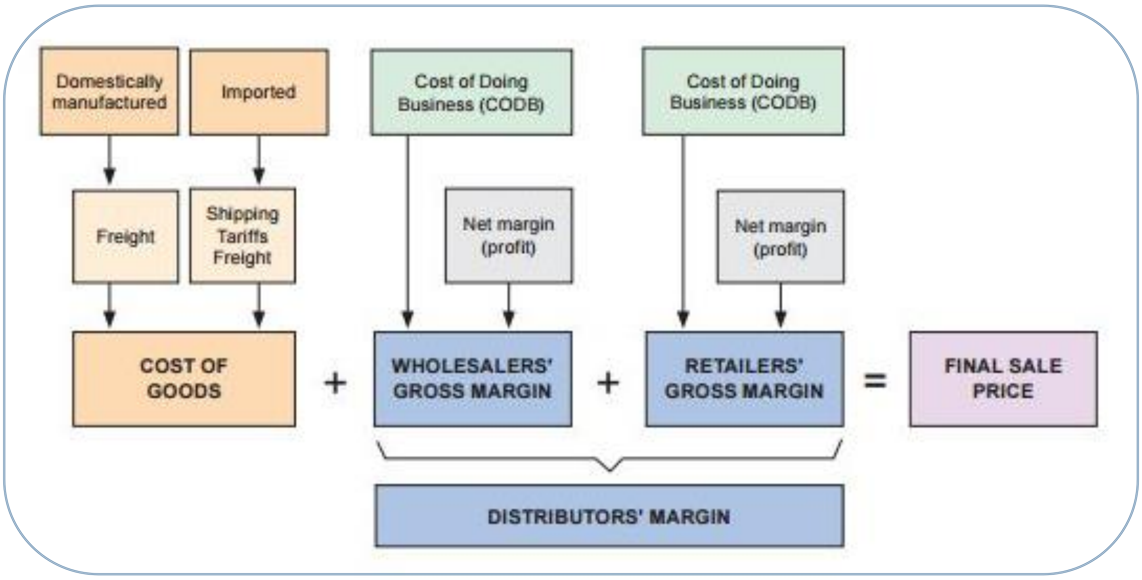

Figure 1: Price calculation structure
Source: D'Arcy P, Norman D, Shan S, *Costs and Margin in the Retail Chain* (2012), p. 15

Price sales is calculated as a cost of goods sold, plus net margin and cost of doing business (which is not necessarily included into final sale price). On the picture above, gross margin form wholesalers is also included, since this model includes wholesaler as one part of the supply chain.

Cost of goods sold can also be reviewed and analyzed as KPI. **The Cost of Goods Sold KPI** measures the actual profit margin on products and services by analyzing how costs such as labor or shipping affect your profit margin. This KPI is instrumental in determining the markup percentage for products and can be a key component in a pricing war with your competition. It's important to remember that even if product is flying off the shelves, you still need to make profit on all that product (Klipfolio, 2016).

Price of the goods is directly linked with the turnover of a retailer, so it is of great interest that a company has a competitive prices. Retailers seek for lowest possible costs of goods, and for the highest possible margins. In that case, the price can be highly competitive in comparison to other retailers.

Seeing the income statement, there is a notion that every position which is presented as a business result (EBIT/EBITDA/EBITDAR) is directly linked with total turnover. In theory, sales is mostly considered as starting position in income statement, but, sales comes from the deference between turnover and VAT (Value Added Tax[5]).

As mentioned before, beside total turnover, turnover could be analyzed as **turnover per employee** (which shows the efficiency of workers) and **turnover per m^2 of shopping space** (which shows the efficiency of used space and it is mostly compared to the cost of rent if that space is not the property of the company).

Total turnover per m^2 (or as it is also called – *Sales per Square Foot*) could be calculated as total net sales divided by net floor space. Net floor space includes only the shopping space (without warehouse and offices if they are integrated within shopping space).

In Table 3, there is a scenario analysis of decision making based on average grocery stores of two biggest retail chains in Serbia: Mercator-S and Delhaize Serbia (considering indicators for three month period including different banners[6]).

On the other hand, turnover per employee is calculated as a quotient between total net sales and FTE (*Full Time Employees*) for a specific grocery store. Top retailers in Serbia, such as Mercator-S and Delhaize Serbia, have the share of rent costs in total turnover 4-5%, which is considered as normal share on this market. For bigger market shops, this percentage could go a little bit higher.

[5] In the Republic of Serbia, VAT has two tax rates: 20% and 10%.
[6] Banners in modern retail include different brands of grocery stores. For example, Mercator-S consists of two banners – Idea and Roda, and both of them include different formats (Small Idea stores, Super Idea, Hypermarkets, etc.). Idea stands for neighbor stores, while Roda has a perception of a family stores, so the banners are percept differently among customers.

Table 4: Turnover per m² / Rent costs per m²

Name of the shop	m²	Total turnover in RSD	Turnover per m² in RSD	Rent costs in RSD per m²	% Rent costs per m²	Opinion
Retail shop 1	592	**30.204.000**	**51.020**	**8.300**	**16.26%**	Retail shop 1 is in comparison to other two shops the worst. Margin of renting costs is 16.26% which is above the average % of rent. This shop is ineffective, considering turnover and rent per m².
Retail shop 2	1401	**132.308.000**	**94.438**	**4.583**	**4.85%**	Retail shop 2 is the best in balance between renting costs and turnover with 4.85% of share in turnover per m². The space of 1401 m² is efficiently used.
Retail shop 3	8924	**802.270.000**	**89.870**	**5.350**	**5.95%**	Retail shop 3 has the biggest quadrature, but still it has a relative good balance between rent cost and turnover per m².

According to analysis in Table 4, retail shop no. 2 is the most efficient in doing business, while retail shop no. 1 is the worst.

Table 5: Turnover per employee

Name of the shop	No. of employees	Total turnover in RSD	Turnover per employee	Average salary in RSD	% Earning costs in turnover	Opinion
Retail shop 1	14	**30.204.000**	**2.157.428**	**269.333**	**12.48%**	Normal share of salary costs in total turnover are moving in the scale 3-6%. According to that fact, retail shop 1 is not so efficient in the use of the workforce.
Retail shop 2	25	**132.308.000**	**5.292.320**	**292.266**	**5.52%**	Retail shop 2 has a good balance between salary costs and turnover per employee and it is the representative of some bigger supermarkets, such as Idea Super or Maxi stores in Serbia.
Retail shop 3	85	**802.270.000**	**8.438.470**	**235.262**	**2.78%**	Retail shop no. 3 is the most efficient with the 2.78% share of salary costs in total turnover. However, shops that size and with lot of employees, have other costs higher, so in the Republic of Serbia, but also in Europe and America, there is a new trend of quick buying.

Indicators such as turnover per m² or per employee are important for middle and lower parts of management in retail, so they are also considered as key performance indicators, based on which, management can make appropriate decisions.

5. THE IMPACT OF PRICING STRATEGIES ON TURNOVER AND GROSS MARGIN INDICATORS

If profit is reviewed as the equation *turnover = price x volume, than, there* are just three turnover drivers: price, volume and costs. Among these components, price is the most effective profit driver.

Profitability is a very important group of indicators in every industry, in retail especially. Without a profitable category of goods and grocery stores, modern retail couldn't exist. Speaking of grocery retailers, with a very low margins, profitability is crucial. Falling into price-promotion traps is hard to manage with both customers and competitors, affecting the terms on the retail market.

During the last few years, price wars has increased the impact on profitability of grocery retailers and has become more fatal for new retailers who enter the market. In the terms of dynamic market, it is really important for a retailer to have a successful and profitable pricing strategies.

There are many pricing strategies, but two of them are mostly used in retail. The first strategy is called "Every Day Low Price" (EDLP) which considers the lowest prices every day for their customers. This strategies is mostly focused on some specific group of products in order to differentiate retailer from its competitors. Wal-Mart is considered as pioneer of the EDLP pricing strategy. It started being popular in the 1990's, but today it is still one of the mostly used pricing strategies.

On the other hand, there is a "High-Low" (Hi-Lo) pricing strategy whereby the retailers set their prices on a higher every day level, but use price discounts and promotions to attract customers.

Researches has shown that the main motivation for using EDLP pricing strategies is cutting down advertising costs and reducing labor as a consequence of cutting back on promotions, but also improving inventory management. Speaking of Hi-Low pricing strategy, it is suggested that the motivation for retailers to use this strategy is to "generate excitement, attract shoppers, clear out time-sensitive merchandise and sell complementary, high-martin items (Voss and Seiders 2003, p. 37).

In theory, using just one pricing strategy doesn't function. Retailers not only use either a Hi-Lo or an EDLP pricing strategy, but follow a "hybrid" pricing strategy containing elements of both Hi-Lo and EDLP. For example, in the German retail market, Rewe is seen as a Hi-Lo retailer, but Rewe also has EDLP elements with its private label brands. On the other hand, for example Aldi and the drugstore chain DM are pursuing an EDLP strategy, but also offer some products on promotion.

An increase in price – holding the volume constant – has a 100% impact on profit, whereas an increase in volume – holding the price constant – just influences the profit to the amount of the additional turnover minus the marginal costs (Husseini, 2015).

Nowadays, there are several methods by which a pricing strategy could be presented to a customers. The mostly used method is loyalty program method. Running a loyalty programs is a huge managerial task. Affecting on the customer perception of loyalty program – coupons, loyalty cards, bonus points, etc. are just the top of the iceberg. Behind that, there are many activities – logistics activities, involving and card issuing, call centers, involving card issuing, negotiation with partners in the scheme and suppliers of bonus merchandise, and so on (Stone, 2004, p. 308).

Tracking the competitor's activities through usage of pricing strategies can be done using different models and methods. One of them is the competitive matrix for pricing strategies (Table 5).

Table 6: Price index matrix - pricing strategies
Source: Blazek A, Deyhle A, Eiselmayer K. (2011), Controlling System, p. 114

Factors	Weight	Scale					Total
		1	2	3	4	5	
In-Store pleasantness	30%					x	150
Online shop	5%			x			15
Assortment	30%				x		120
Loyalty programs	5%				x		20
Time spend queuing	30%		x				60
Total	**100%**						**365**

The matrix consists of factors whose importance is determined by the sum of weighting to give 100%. It also contains the scale of 1-5, which is estimated ratio compared to competitor (1- much worse, 2 - worse, 3 - the same, 4 - better 5 - much better). Multiplying the scale of weights we get the total amount. The competitor automatically has a total amount of 300 (by multiplying the sum of all weights - 100 with the number 3).

Comparing the ratio obtained by our company and the number 300, we get a percentage which shows should the company increase or decrease the prices in comparison to the main competitor. If that ratio is higher than 1, than the company has the potential to increase the prices of its goods, and in opposite, to decrease prices.

For the analysis of the factors and assessing whether the factor determined by the company is better than a competitor, it is necessary to do more detailed quantitative analysis, and even seek the help of consultants and research agencies. If we compare company X with company Y – main competitor, on the given example in table above, the calculation has given the sum for company X of 365. If that amount is divided with 300 (competitors score), the comparing ratio is the number 1,215. That means that for the company X it is justified to increase prices by 21.5%.

6. CONCLUSION

Managing key performance indicators is crucial for all retailers. There are two main types of indicators which are mostly used in every business. Key performance indicators (KPI's) doesn't necessarily have to include only financial indicators (sales, EBIT, EBITDA, etc.), but could also include some non-financial indicators as well. Choosing the proper indicators is crucial for every business. But, it is important to put the accent on the different aspects of reviewing selected indicators. Top management and other lower parts of management doesn't consider every KPI with the same importance. Turnover and gross margin are two basic indicators in grocery retail. They are tracked by every level of management, but there are some more specialized indicators such as sales per square foot or turnover per employee which are more interested to lower levels of management (for example managers of grocery stores) than to the top management. With low margin levels, grocery retailers must establish higher turnovers in order to have a profit and to do business with a certain level of sustainability. However, there are several factors directly affecting on gross margin and total turnover. Two of them are prices and the quantity of goods sold. Speaking of prices, grocery retailers are mostly using two pricing strategies: EDLP (*Every Day Low Prices*) and Hi Lo (*High-Low*). Nowadays, retailers use hybrid pricing strategies – combining both mentioned pricing strategies with a planned combination for different groups of goods. It is up to category managers to plan those strategies carefully and to track changes on the retail market in order to establish target. Having a strong and consistent pricing strategies will provide to a retailer a competitive advantage on the long terms. All in all, with the proper analysis, use of key performance indicators and proper mix with adequate pricing strategies, retail chains can run toward leading positions on the retail market. Customers are mostly attracted by location of the grocery store and by the kindness of employees (GfK Market Research, 2015). Considering that fact, there is still enough space for additional research of turnover, and the impact of employee's satisfaction and efficiency of selling space on total turnover.

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OPEN SOURCE ENTERPRISE RESOURCE PLANNING: SOLUTION FOR PRODUCTION PLANNING IN SMEs

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Abstract: *This paper presents the study on open source Enterprise Resource Planning (ERP) software from the perspective of their production module. The study was based on the survey of five open source ERP software. The survey method was content analysis. The observed ERP solutions were evaluated, in a qualitative way, regarding important functionalities and analysis tools of their production module. Besides that, the paper is also focused on capabilities, advantages, and shortcomings of open source ERP solutions for small and medium-sized enterprises. The purpose of this paper is to further present information and knowledge about reasons for SMEs to adopt open source ERP. One of the goals is also to promote alternative ways of supplying SMEs with adequate management and IT solutions. In this paper, analysed and presented open source ERPs (Oddo, WebErp, OpenBravo, Compiere, and NextERP) have proved to be very useful and equipped solutions for SMEs production planning. The findings of this paper are interesting both for scholars and practitioners (including SMEs) as well as for ERP developers.*

Keywords*: Enterprise resource planning (ERP), small and medium-sized enterprises (SMEs), production planning, open source ERP*

1. INTRODUCTION

Contemporary planning and management cannot be imagined without the usage of information and communication technology (ICT). According to the American Production and Inventory Control Society - APICS (Cox & Blackstone, 2005), Enterprise resource planning (ERP) is defined as a „*method for the effective planning and controlling of all resources needed to take, make, ship and account for customer orders in a manufacturing, distribution or service organization*". ERPs are often defined as standardized packaged software designed to integrate an organisation's entire value chain (Johansson & Sudzina, 2008). According to Heizer and Render (2011), Enterprise Resource Planning is software that allows companies to: (1) automate and integrate many of their business processes through planning of enterprises resources; (2) share a common database and business practices throughout the enterprise; (3) produce information in a real time. At the strategic level, ERP system presents an application programme that integrates all business functions and processes (Loh & Koh, 2004). At the operational level, ERP is the system for planning and monitoring resources of manufacturing, i.e. manufacturing resource planning system (Loh & Koh, 2004).

The roots of ERP system originated in the manufacturing industry in the 1980s, through the development of Materials Requirement Planning (MRP) method and Manufacturing Resource Planning (MRP II) concept (Kilic et al., 2015). Later it evolves in the integral information system with different modules for resource planning and management of production, service and commerce. The core modules included in ERP are (Zhang et al., 2005; Madanhire & Mbohwa, 2016): *Production planning* module with the primary purpose to optimize the utilization of manufacturing capacity and material resources using historical production data and sales forecasting; *Purchasing module* facilitates procurement of required raw materials, and automates the process of placing orders to suppliers; *Inventory control module* enhance the process of maintaining appropriate stock level and identifying inventory requirements; *Sales module* helps in order placement and scheduling, shipping and invoicing; *Marketing module supports* marketing activity and campaign; *Financial module,* as the core module, collect and integrate financial data from every department and generate financial reports and statements; *Human resources module* retains a complete database with information about employees. Thus, ERP software system is a comprehensive system which consolidates all departments from purchasing via production to distribution in one integrated system and manages it (Madanhire & Mbohwa, 2016). Furthermore, according to Ruivo, Oliveira, and Neto (2015), ERP system provides process-oriented business management view which is more effective and organised way of executing business operations then the functions-oriented. So, one of the main advantages generated by the implementation of the ERP system is integration between enterprise's departments and processes throughout the ERP modules, with achieving different operational performances such as: improved productivity, lowered costs, more reliable performances, reduced paperwork, and saved time (Antoniadis, Tsiakiris, & Tsopogloy, 2015). In the last ten years, besides the conventional ERP systems, the focus is on the open source, cloud and mobile ERP systems, especially their application in small and medium-sized enterprises (SMEs). A comprehensive literature review in ERP field is presented in Huang & Yasuda (2016).

The development of ERP for SMEs rose from two sources: the first is the business needs of SMEs, which become more complex in global business and supply chain environment; and the second is saturation of large companies' market demand. In that situation, ERP producers introduce solutions for small business. Corresponding to Ruivo, Oliveira & Neto (2015) the most literature studies are about ERP comparisons regarding the selection process and, implementation duration and costs. However, little studies examined ERP implementation in SMEs and even less described the comparison of different ERP products. Besides that, Huang and Yasuda (2016) deduced that research on SMEs and ERP will continuously increase, mainly because many new ERP producers provide different solutions that can be easily implemented and maintained by SMEs. Several years before, Johansson and Sudzina (2008) stated that there is tremendous interest in free and open source ERP systems. Due to previous, the authors of this paper consider Open Source ERP in the context of SMEs as a very actual research topic.

In this paper, we will analyse and compare five Open Source ERPs software observing their production planning module. Our main research question was: Are the Open Source ERPs software appropriate for SMEs? The rest of the paper is organised as follows: Section 2 introduces the concept of production planning. Section 3 describes ERP through SMEs point of view. Section 4 presents the qualitative evaluation of observed software concerning their production module. Section 5 concludes the paper.

2. ENTERPRISE PRODUCTION PLANNING

Planning as a management phase includes defining the objectives, as well as activities and resources which are necessary for achieving the proposed objectives, taking into account all constraints (Omerbegović-Bijelović, 2006, p. 36). Broadly observed in business operations of every enterprise, planning is concerned with the adjustment between what the market requires and what the operation's resources can deliver (Slack, Chambers, & Johnston, 2007, p. 290). The domain of production and service planning are the defined goals and activities which are conducted with appropriate resource usage, in order to obtain efficient and effective production and servicing process.

The process of operations planning (production and service delivery) initially start from the demand forecasting of product and services. On the basis of anticipated demand, long-term needs for capacities of production and service provision are planned. Long-term capacity planning decisions are a framework for planning capacity and demand on mid-term – which is the information input in the process of aggregate planning. Aggregate planning includes defining the strategy on a mid-term (3 to 18 months) for engagement of human resources, production capacities, quantities of different categories of product and services, inventories, overtime work and subcontracting, all with the aim of cost minimization. After aggregate planning, next phase is master production scheduling. Master Production Schedule (MPS) defines planned quantities of different product and service varieties in planned time for its realisation. MSP is the result of aggregate plan decomposition. MPS together with bill of material present the basis for the next phases of production planning: *Material Requirements Planning (MRP),* negotiating and selections of suppliers, contracting of supplies, raw material and components ordering, time scheduling of production activities on different machines and workers, production orders launching, dispatching material in the production process (Omerbegović-Bijelović, 2010). Presented concept of production planning doesn't have to refer to only one company. The modern trend in management involves the orientation on the networks of production and service enterprises which are in customer to supplier relation, known as supply chain or value chain (Omerbegović-Bijelović, Atanasov & Rakićević, 2014). The task of planning is more complicated at enterprises that are in the supply chain because it is necessary to define plan for all of the enterprises which are connected to each other.

According to the authors (Schut, 2004, p. 219; Gansterer, 2015), production planning (including whole Supply Chain) covers the following areas: Sales forecasting, quantitative support for sales and operations planning, integrated supply chain tactical planning, production requirements calculation from distribution network requirements, master production scheduling, detailed scheduling of production, inventory deployment planning in a distribution network and short-range transportation planning.

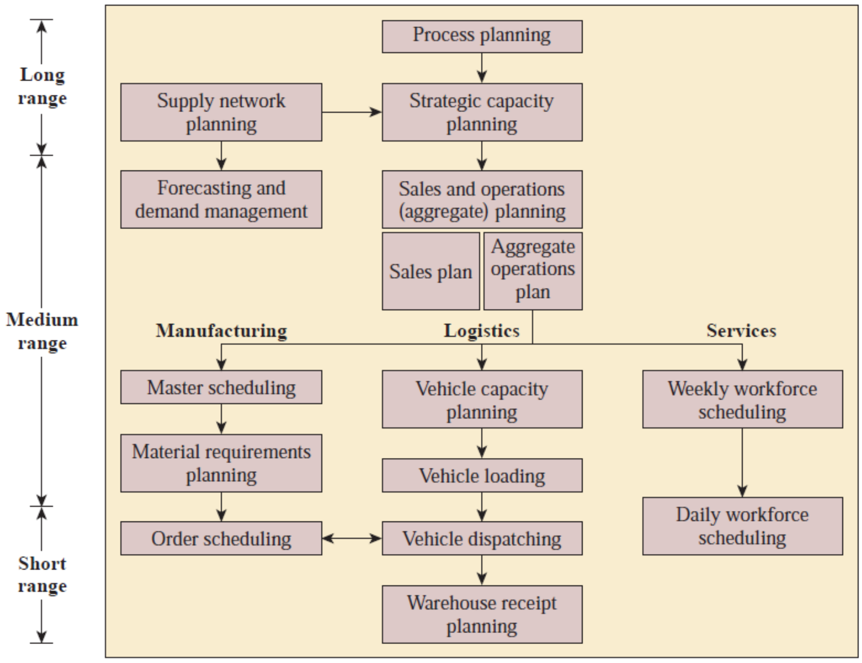

Figure 1: Main activities in planning of production and servicing operations
Source: Jacobs & Chase (2010, p. 286)

Junior & Filho (2012) in their paper defined next production planning activities: product demand forecast, aggregate planning, determining of the master production schedule, inventories planning, capacities planning, determining production order quantities, scheduling of production activities.

3. SMALL AND MEDIUM-SIZED ENTERPRISES AND ENTERPRISE RESOURCE PLANNING

Surveys and studies relating to the implementation of enterprise resource planning (ERP) systems in small and medium-sized enterprises (SMEs) has been rapidly increasing in recent years (Loh & Koh, 2004). Mabert et al. (2003), presented the difference between large and small and medium-sized enterprises in their implementation of ERP software. They approved that large companies customize ERP software more often while small enterprises adopt business processes within ERP systems. Besides that, large companies reported greater benefits in the financial areas, while small companies report more benefits in manufacturing from their ERP implementations. SMEs, which are in a supply chain, that deals with large enterprises and have an ERP system with production planning module will provide better performances in manufacturing, like *productivity*, *customer services*, *inventory turns* and *reduction in material cost* (Mabert et al. 2003; Loh & Koh, 2004).

Antoniadis, Tsiakiris & Tsopogloy (2015), in their survey based on respondents' opinions, identified the following key benefits of ERP utilization in the SMEs: data integration from different departments, reliability of information, saving time by automating procedures, controlling activities and flexible decision making. However, the cost reduction was the less important advantage of implementing the ERP system in the company, despite the fact that during crisis periods, reducing cost is essence for SMEs. The same authors present the main disadvantages and deterrents for ERP systems adoption: cost of initial setup and support and, the cost and time required for training the personnel to handle the new ERP system. Ruivo, Oliveira & Neto (2015), also defined benefits of using ERPs: ERP systems allow information to flow transparently in a firm's ecosystem, benefiting its supply chain efficiency; ERP systems can bring operational excellence and competitive advantages to firms.

Obvious benefits of ERP software can be achieved if its implementation was successful. Antoniadis, Tsiakiris & Tsopogloy (2015) presented the most important factors for successful implementation of ERP in SMEs: Appropriate ERP provider support, ERP customization and parameterization, ability of communication and cooperation between all the involved enterprise departments, personnel's training and education, level of quality service in external technical support for the ERP. Beside this, in comprehensive analysis Upadhyay et al. (2010), identified several critical factors: 1) Education and training to enhance SMEs employees knowledge and proficiency; 2) Clearly defined goal and scope of ERP implementation; 3) Top management support through providing necessary resources and providing leadership; 4) Proper project planning due to constrained SMEs' resources; 5) Minimal customization (fit the organisational needs to the functionality of ERP); 6) Proper implementation strategy ("Big bang" or "vanilla" approach).

Resource constraints of small business are huge obstacle for purchasing of ERP system. One of the possible options for SMEs is to implement Open Source ERP software. Johansson and Sudzina (2008) presented initial literature review about open source ERP and SMEs. They also identified the lack of studies about why SMEs choose open source ERPs instead of proprietary ERPs and try to bridge it within their survey.

The SMEs present backbone of the Serbian and European economy. Every study about improving SMEs' competitive advantages as well as their further development has vital importance. Adoption of ERP system is one of the most important technological and organizational innovations in modern SMEs, since it promotes knowledge diffusion, and accelerates their business decision-making processes. Therefore, a good consideration and multi-criteria analysis should be applied in a selection process (Kilic et al., 2015).

4. COMPARATION OF THE OPEN SOURCE ERP SOLUTIONS

Before the comparison among Open Source ERPs will be presented, it is necessary to remark that three best-known ERP vendors (SAP, Oracle, and Microsoft Dynamic) take about 55% of the market share. The commercial prices of mention proprietary ERP solutions are among 5.000 up to 250.000 $. (Top ten ERP vendors in 2016, https://www.top10erp.org). The result of this fact is that SMEs, especially those that are micro and small, can't afford proprietary ERPs, and they turn to open source solutions.

The term "open source" refers to something that can be modified and shared because its design is publicly accessible (https://opensource.com/resources/what-open-source). While it originated in the context of computer software development, today the term "open source" designates a set of values - what we call *the open source way*. Open source projects, products, or initiatives are those that embrace and celebrate open exchange, collaborative participation, rapid prototyping, transparency, meritocracy, and community development. Open source software is software which source code is available for modification or enhancement by anyone. Open source software is partially free and comes with the open source code that has possibilities to be adjusted and changed according to users' needs (Riehle, 2007). Sometimes open source software licenses provide users possibilities to redistribute the software.

There are two types of open source software: *Community open source* is software where broad community of volunteers are developers; *Commercial open source* is software that a for-profit entity owns and develops. The owner company maintains the copyright policy and determines what can be changed and implemented in software code (Riehle, 2007). Commercial open source software is usually available for free to non-profit users. Sometimes, for commercial users, it is free as well. In that situation companies make money by providing support services and selling software upgrades. Really interesting businesses are companies and individuals (known as committers) that provide IT services for different open source software.

Even though that open source software are initially free, they could have cost related to the usage (cost of learning, cost of adjustment and cost of maintenance). The main implementation problem of ERP software, both proprietary or those that are open source, is unsuitability between ERP functionality and company requirements (Johansson & Sudzina, 2008). Project of ERP implementation requests that organization changes processes or adjusted ERP solution according to them. However, in the case of process changes, one of the big advantages for SMEs is their small scale and, consequently, flexibility and adaptability. Besides that, in the case of ERP customization, the great characteristics of open source solutions is that they present: process delivery model (that can be implemented) and, development model that need to be tailored.

Decision process for implementation open source ERP in SME may include the evaluation of different ERP characteristics: usability, compatibility, features, support cost and, software reliability (Johansson & Sudzina, 2008). Kilic et al. (2015) defined three groups of evaluation criteria: Business criteria (brand image and market position), Cost criteria (purchasing cost, implementation cost, and support cost) and technical criteria (functionality, reliability, compatibility). Business criteria are brand image and market position; cost criteria are purchasing cost, implementation cost and support cost; while technical criteria are functionality, reliability and, compatibility.

In analysis, which will be presented underneath (Table 1), ERPs' production module features will be observed. First, every analysed open source ERP (Odoo, WebERP, OpenBravo, Compiere and ERPNext) will be described in a few sentences.

Odoo ERP (previously titled TinyERP) is partially free open source ERP for all size-companies. For two users when the system is hosted online, it is free. For the off-line version intended for larger number of users, it is not. Besides that, Odoo is totally free for in-house maintenance. This software covers all standard modules and functionalities (the application suite includes: billing, accounting, manufacturing, purchasing, warehouse management, and project management) and is perfect for managing small business lower than 50 employees (http://www.odoo.com).

WebERP is an open source ERP system for SMEs. WebERP is a complete web based business management system that requires only a web-browser and .pdf reader to be used. It has a wide range of modules and features suitable for many businesses particularly distributed businesses in wholesale, distribution and manufacturing. Due to its on-line hosted nature, it is less hardware demanding than others off-line solutions (http://www.weberp.org).

OpenBravo ERP is a commercial on-line ERP based on a modular system for small and medium-sized companies. The software comes in three editions depending on the needs of particular organization. OpenBravo Community Edition is the free of charge that offers reduced functionalities in compare to payable versions (Enterprise and Professional edition). These editions include some premium, commercial modules — like financial management and inventory management — that many businesses find necessary. This program is among the top ten most active projects on *SourceForge* - centralized Web-based service for control and management of free and open-source software projects (http://www.openbravo.com/).

Compiere is the open source and cloud-ready ERP solution for SMEs in distribution, retail, manufacturing and service industries. Compiere automates accounting, supply chain, inventory and sales orders. It is one of the successful open source projects with more than 1.8 million downloads till nowadays. Compiere includes wide range of modules and encourages enterprises to customize and match Compiere towards they business needs (http://www.compiere.com/).

ERPNext is the on-line open source ERP solution designed for small and medium businesses and is presented as a series of applications. ERPNext covers many business functions including accounting, inventory management, Customer Relationship Management (CRM), purchasing, project and task management, human resource management and manufacturing. ERPNext is very easy to set up, using simple forms to enter information about business in typical setup wizard style. This solution very quickly becomes familiar as the ERPNext is very user-friendly (https://erpnext.com/).

Table 1 shows evaluation of observed open source ERP solutions from perspective of their manufacturing module with contained production planning tools: Manufacturing order, Bill of material, Production costs, Order planning, Aggregate planning, Master production schedule, Gantt chart planning, Quality control planning and reports, MRP (Material requirements planning), Sales and production forecasting, Traceability of products, Product manufacturing routings, Inventory management (receipts, internal transfers, delivery orders), Automated purchase orders, ABC inventory analysis, Inventory algorithms, Production scheduling, Production and inventory reports, Capacity requirements planning, Product lifecycle management, Maintenance planning. Besides that, we examine: ERP solutions' connectivity with other applications and programs; whether solution is available for online/cloud usage; is there option for multilingual customization (particularly for the Serbian language); what is the initial price in the form of licence fee for obtaining observed ERP solutions.

Table 1: The evaluation of Open source ERP solutions

Tools of manufacturing module:	**Open source ERP solutions**				
	odoo	webERP	openbravo	Compiere	ERPNext
Manufacturing order	✓	✓	✓	✓	✓
Bill of material	✓	✓	✓	✓	✓
Production costs	✓	✓	✓	✓	✓
Order planning	✓	✓	✓	✓	✓
Aggregate planning	x	x	x	x	x
Master production schedule	✓	✓	✓	✓	x
Gantt chart	✓	x	x	x	✓
Quality control planning	✓	✓	x	x	✓
MRP	✓	✓	✓	✓	✓
Sales & Prod. forecasting	✓	✓	✓	✓	x
Traceability of products	✓	x	x	✓	✓
Product manufacturing routings	✓	x	x	✓	x
Inventory management	✓	✓	✓	✓	✓
Automated purchase orders	✓	✓	✓	✓	✓
ABC inventory analysis	x	x	✓	✓	x
Inventory algorithms	x	x	✓	x	x
Production scheduling	x	x	x	✓	x
Prod. & inventory reports	✓	✓	✓	✓	x
Capacity requirements planning	x	x	x	✓	✓
Product lifecycle management	x	x	x	x	x
Maintenance planning	x	✓	✓	x	✓
Manufacturing type	Discrete	Discrete	Discrete	Discrete	Discrete
Connectivity	CSV/XLS/ XML/ODS	PHP/ CSV	XML	CSV/XML/XLS DOC/PDF	CSV/XLS
On-line/cloud	✓	✓	✓	✓	✓
Multilingual	✓	✓	✓	✓	✓
The Serbian language	✓	x	x	x	x
Licence fee	240$ per user per year	0$	4.500$ for professional edition	0$	300$ per user per year

According to the analysis in Table 1, all solutions are well equipped. Although presented solutions are generally among each other's, still some solutions that dominate in particular features:

- Aggregate planning is not possible with observed ERPs;
- Planning with Gantt chart is present in Odoo and ERPNext;
- Quality control planning are available in Odoo, WebERP, and ERPNext;
- Sales and production forecasting are part of all observed open source solutions, except for ErpNext;
- Traceability of products is available in Odoo, Compiere and ERPNext;
- Manufacturing routings are available in Odoo and Compiere;
- ABC inventory analysis is only present in OpenBravo and Compiere;
- Inventory algorithms are only present in OpenBravo;
- Production scheduling is part of Compiere, though advanced production scheduling and optimization in not part of any observed software in Table 1. This functionality is still unreachable for this softwares;
- Capacity requirements planning is available in Compiere and ERPNext;
- Product lifecycle management is unavailable in all observed solutions;
- Maintenance planning is included in WebERP, OpenBravo and ERPNext;
- All analysed open source ERPs are intended for discrete type of manufacturing;
- Comprehensive ability for connection with other software and platforms have Odoo and Compiere (CSV/XLS/XML/ODS/PDF);
- Every observed ERPs are available in on-line/cloud version;

- Language of platform: all software are multilingual. The Serbian language is only available for Odoo;
- Licence fee: WebErp and Compiere are free of licence cost.

Although every analysed software has one or more omitted tools and features for production planning, the authors of this paper believe that they are excellent and very economical choice for SMEs. This attitude is also strengthened with fact that open source ERPs have possibilities for adjustment and upgrade in accordance with their open source code.

5. CONCLUSION

The study presented in this paper aimed at investigating the capabilities of production module of open source ERP software for small and medium-sized enterprises. The analysed sample was consisted of five open source ERP solutions, which were compared with set of common features of their production module. The analysis showed that open source ERP have wide range of possibilities, as well as that there are dominated open source ERP solutions for particular features: a) Zero licence cost (for WebErp and Compiere software); b) Excellent language customization (especially Odoo for the Serbian language); c) Connectivity with other software for data export and import (Odoo and Compiere); d) Modern planning methods and tools: Gantt chart (Odoo and ERPNext), sales and production forecasting (Odoo, WebERP, OpenBravo, and Compiere), traceability of products (Odoo, Compiere, and ERPNext), product manufacturing routes (Odoo and Compiere), ABC inventory analysis (OpenBravo and Compiere), inventory algorithms (OpenBravo), production scheduling (Compiere), capacity requirements planning (Compiere and ERPNext), maintenance planning (WebERP, OpenBravo, and ERPNext);

Open source ERP software present great opportunity for small business due to their initial cost and adaptable nature. Serrano and Sarriegi (2006) stated that benefit of applying open source ERP solutions are greater than for other applications. This is reflected in: 1) Increased adaptability of ERP solutions due to full access to source code; 2) Decrease dependency on single supplier – companies that purchase a proprietary ERP are highly dependent on the software producers or distributors; and 3) Reduced costs – open source ERP usually avoid licence costs, and if the consultant charge for customization is not high it will result in lower cost of implementation.

The results of this study can be used for the practical and theoretical purpose. Regarding the practical, implications it can be useful for owners and managers of SMEs to support a technological and organizational development of their small businesses. Theoretical implications are reflected in knowledge contribution to scientific fields of production planning and management of SMEs. Further research will be focus on detailed analysis of the wider group of open source ERPs as well as surveys of SMEs, their management problems and detail needs for ERPs implementation.

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GPI PROCESS PERFORMANCE MEASUREMENT MODEL

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Abstract: *This paper investigates the possibility of developing flexible process performance measurement model. The results of comparative analysis of existing process performance measurement models suggest that they lack flexibility, ie the ability to use model in a wide and varying range of companies, with no significant changes in the model. New GPI process performance measurement model (in the narrow version) is proposed, that has improved flexibility compared to existing process performance measurement models. Results of case study show that proposed model can create basis for effective performance management, and also for further research in this area.*

Keywords*: process performance measurement, goals, key processes, process performance indicators, flexibility*

1. INTRODUCTION

In order to achieve sustainable performance of business system, it is crucial for companies to manage its processes, and process management requires the continuous measurement of their performances. In the literature, as in practice, there are number of models and frameworks that provide guidelines for the performance measurement system development and review performance measurement problems from different perspectives. Besides tendency to link operations and processes to strategic goals, they integrate financial and non-financial measures, and focus all business activities on customer requirements (Lynch & Cross, 1995, p.6). Nevertheless, these different approaches have led to numerous definitions of a performance measurement system, but still, there is little consensus regarding its main components and characteristics. (Dumond, 1994, p.17).

Since the environment in which the organizations operate is dynamic and success depends upon meeting the changing needs of all stakeholders, it is necessary for organizations to evaluate performance from an external perspective, listening to customers, suppliers and other stakeholders (Striteska & Spickova, 2012, p.1). Also, the organization goals need to be changed over time and when goals change, some performance measures (indicators) must be changed too. According to Franceschini et al. (2007, p.55), one of the most critical aspects in operations management is “translating” a company’s goals into performance indicators.

Nowadays, there are a number of performance measurement (PM) models that include or strongly rely on performance planning, job design, performance measures determination and monitoring, and on the reward system definition (Sikavica & Hernaus, 2011, p.433). Those frameworks assist in this performance measurement system building process by clarifying boundaries, specifying dimensions or views and may also provide initial intuitions into relationships among the performance dimensions (Rouse & Putterill, 2003, p.792). Various PM models consider performance from different perspectives, and they are designed for different purposes. Majority of them takes into account the strategy or goals while determining performance, but none of analysed models link directly organizational goals and performance indicators, in other words, they don’t specify their interdependence, which would allow model flexibility. There is, therefore a need for improving the flexibility in the performance measurement models.

The development of PM model, that starts from the strategic objectives defined in accordance with the stakeholders' requirements, and translates them on the goals of lower hierarchical levels, and then connects them with key performance indicators processes (which realize defined objectives), will allow the connection of strategic objectives and key process performance indicators. By this, the flexibility of the model, ie its simple and easy applicability in the various organizations, can be increased.

In the paper, after the brief literature review about process performance indicators and PM models, research hypothesis is proposed. After that, the methodology of research is described. Then, the initial model was proposed, and the case study research was described. Based on the study findings, previously conceptualized model is improved. At the end, some conclusions are drawn, as well as the directions of future research.

2. LITERATURE REVIEW AND HYPOTHESES

2.1. Process performance indicators

A process performance indicator is a measure that reflects the critical success factors of a business process defined within an organisation, in which its target value reflects the objectives pursued by the organisation with that business process (Del-Río-Ortega, Resinas & Ruiz-Cortés, 2010, p. 555). Key performance indicators (KPIs) provide a valuable source for the translation of strategic objectives to process-specific goals and facilitate effective process control (Rosemann & vom Brocke, 2010, p.115).

Although most authors agree that the performance indicators have to be linked to the organization's strategy and objectives, there is no unique and universal approach to determining performance indicators. Turajlić et al. (2009) proposed Strategic Alignment Pyramid for ilustration the process of KPI determination. Parmenter (2010) proposed the 12-step model for development and usage of KPIs. Franceschini et al. (2007) sugesst 5-step approach that contributes to improved organization for measurement performnse system development.

Many authors defined the specific lists of performance indicators for certain types of organizations or business areas (Sikavica & Hernaus, 2011; Parmenter, 2010; Supply-Chain Council, 2010; Addison et al, 2009). Besides Parmenter's list (Parmenter, 2010), which can be considered as universal, all other examples of performance indicators' lists are limited to a specific area or performance perspective.

2.2. Process performance measurement models

In the literature, as in practice, there are number of models and frameworks that provide guidelines for the performance measurement system development. The objective for such models is to help organizations to define a set of measures that reflects their objectives and assesses their performance appropriately (Kennerly & Neely, 2002, p. 146). Besides tendency to link operations and processes to strategic goals, they integrate financial and non-financial measures, and focus all business activities on customer requirements (Lynch & Cross, 1995, p.6). Nevertheless, these different approaches have led to numerous definitions of a performance measurement system, but still, there is little consensus regarding its main components and characteristics (Dumond, 1994, p.17).

Some of the most common models in the literature are: Tableau de Bord - TB (de Guerny et al, 1990; Neely et al, 2007), Activity based costing – ABC method (Budd, 2010), Data Envelopment Analysis - DEA (Berg, 2010; Savić, 2012), Theory of Constraints - TOC (Goldratt, 1984), Performance measurement matrix (Keegan et al, 1989; Neely et al, 2007), Performance pyramid (Lynch & Cross, 1991), Framework of results and determinants (Fitzgerald et al, 1991; Neely et al, 2007), Balanced Scorecard - BSC (Kaplan & Norton, 1993), EFQM model (Neely et al, 2007; EFQM, 2009), DOE/NV model (Bellman et al, 1994; Franceschini et al, 2007), TQM performance measurement model (Sinclair & Zairi, 1995; Sinclair & Chang, 2002), Brown's performance measurement concept (Brown, 1996;), Supply Chain Operations Reference (SCOR) model (Supply-Chain Council, 2010), Demand to measure model - DtM (Ljungberg, 2002), Kanji Business Excellence Measurement System - KBEMS (Kanji, 2002; Naghavi et al, 2012); Business System Design Decomposition framework - BSDD (Taticchi et al, 2010).

2.3. Comparative analisys of PPM models

Those models were according to twelve criteria (Simeunović, 2015). One of the criteria was model flexibility, which implies the ability to use models in a wide and varying range of companies, ie model applicability in a number of companies, with no significant changes in the model. For research purposes, model flexibility is defined on the four levels, as shown in Table 1.

The results of comparative analysis show that five models are applicable to all organizations without major changes, but these models are limited to the level of processes, ie do not consider organization as a whole. Six models can be applied in different type of organizations, but only to a certain level, ie performance indicators must be defined again for each organization, and that's time consuming, so they can not be considered as fully flexible models. Only two models (EFQM, TOC), according to the results of the analysis, have sufficient flexibility.

However, EFQM model is not recommended to be used in developing countries, because of high demands on achieving business performance, so it is not suitable for use in the companies in Serbia. From the other hand, Theory of constraints is far from being a complete performance measuring system (Striteska & Spickova, 2012, p.9), and it is difficult for applying in changing environment. Based on previous, it can be concluded that the flexibility of analyzed PM models is not satisfactory.

Table 1: PM model classification - model flexibility aspect (Simeunovic et al, 2015)

Level	Description of level	Model
1	Model is not flexible, ie it is defined only for specific type of organizations	Framework of results and determinants, TQM, SCOR
2	Model is flexible to some extent, ie, it is applicable in all types of organizations, but with significant changes in the model	TB, PM matrix, Performance pyramid, BSC, DOE/NV, BSDD
3	Model is flexible, ie, it is applicable in a wide and varying range of companies, but only at process level (not at whole organization level)	ABC, DEA, Brown's model, DtM, KBEMS
4	Model is fully flexible, ie it is it is applicable in a wide and varying range of companies, with no significant changes in the model	TOC, EFQM

Therefore, there is the need for rapid adjustment of PM system to changing business environment. The development of PM model, that starts from the strategic objectives defined in accordance with the stakeholders' requirements, and translates them on the goals of lower hierarchical levels, and then connects them with key performance indicators processes (which realize defined objectives), will allow the connection of strategic objectives and key process performance indicators. By this, the flexibility of the model, i.e. its simple and easy applicability in the various organizations, can be increased.

2.4. Hypotheses

Based on previous, the following general research hypothesis is proposed:

H0. By defining a universal set of goals at the highest level of the organization, a universal set of goals of organizational units and the universal set of process performance indicators, the PM system flexibility could be improved.

To examine this general hypothesis more thoroughly, it is separated into five smaller sub-hypotheses:

H1: By applying the process management based PM model is possible to define the higest level goals of organization in accordance with the stakeholders' requirements.

H2: The highest level goals of organization can be generalized (the universal set of highest level goals can be defined).

H3: By decomposing the highest level goals to the goals of organizational units, key processes can be identified.

H4: By applying the process management based PM model is possible to identify proces performance indicators.

H5: It is possible to identify the universal set of process performance indicators, which can be measured and monitored in each process-orientied bussines system.

3. RESEARCH METHODOLOGY

In order to test the proposed hypotheses, it was decided to conduct case studiy research on the domestic market. Although geographical area wasn't significant, due to the possibility of data collection, research was limited to Serbia. Case study was conducted according to guidelines for case study research proposed by Eisenhardt (1989).

During planning research, intention was to test initial process management based PM model in process-oriented organizations, and then, to analyse decomposition of stretegic goals of organization onto the organizational units' goals, as well as their conection with key process performance indicators.

The unit of analisys for the case study was bussines system, i.e. organization. Selection criteria were designed process model in the organization, and data availability (possibility of data collection). Research was conducted from October 2011 to February 2013. Proposed model was tested at 31 cases, i.e. in 31 organization.

During the research, detailed examination of the documentation on the strategic goals and organizational processes was performed. In order to obtain insight about selected organizations, available documentation from the organizations' web-sites, as well as information on the current PM practice were thoroughly reviewed. The proposed PM model was tested in all selected organizations, and the obtained results were further used for testing hypotheses, as well as for the model improvement.

4. CASE STUDY RESEARCH

4.1. Description of initial PM model

The first step in establishing process-oriented performance measurement system is the development of mission and vision statement. The mission can be seen as the far goal that may never be reached. It should describe what the organization is in business to do. The vision is where the company wants to go, the ideal future state of the organization. Well-defined mission statement should facilitate product/service identification, on the one hand, and identification of stakeholders, and their requirements, on the other hand. Vision statement, along with identified stakeholders, are the basis for defining those product/service quality features by which the organization meets the requirements of stakeholders. Considering the importance of stakeholders for the success of the organization, their requirements should be than incorporated into the strategy and translated into measurable organizational goals. Furthermore, company should decompose those organizational goals to lower level goals of organizational units. At the same time, according to mission, the basic product/service (or more basic products/services) should be identified, and the product/service catalogue should be created, which is the basis for business process identification, i.e process model design. Next step is to identify those processes and activities that (from process model) lead to achievement of organizational goals, and whose performance indicators should be measured. However, since it is impossible to simultaneously improve all processes, or to measure performances of all processes, due to limited resources and time, considering that all performances are not equally important, efforts should be focused on measuring the performances of those processes whose execution contributes to achievement of the organizational goals or stakeholders requirements. So, the list of prior, critical and key processes should be created, whereby the key processes are those processes through which the specificity of business system can be recognized and which contribute to business system goals realization. Given the above mentioned, it is necessary to select the key processes that will be measured and managed. The next step is to translate the top level goals into key process performance indicators which lead to the achievement of these goals. The degree to which goals, as a mission, are met is determined by measuring and comparing process performance with a defined goal (Simeunović et al, 2014).

Translation process is performed as follows. The strategic goals of the organization, aligned with the requirements of stakeholders, are decomposed into the lower level objectives, i.e. objectives of the business system units. If an organization achieves goals of its organizational units, the highest level goals will be achieved too. In this step, it’s necessary to define the units of measurement, reference values (values that are required for goal achieving), the method of measuring these goals, and to describe how (in which interval) the trend of achieving these goals will be followed. Next step is to determine which processes in organization should be performed in order to achieve those second level goals. Then, for each of these processes, performance indicators which will be measured and monitored, have to be defined. In this way, process performance indicators are directly linked with organizational units’ goals, but also, indirectly, with the highest level goals of organization. The logic and procedure for translating the business system's goals in process performance indicators are shown in Figure 1.

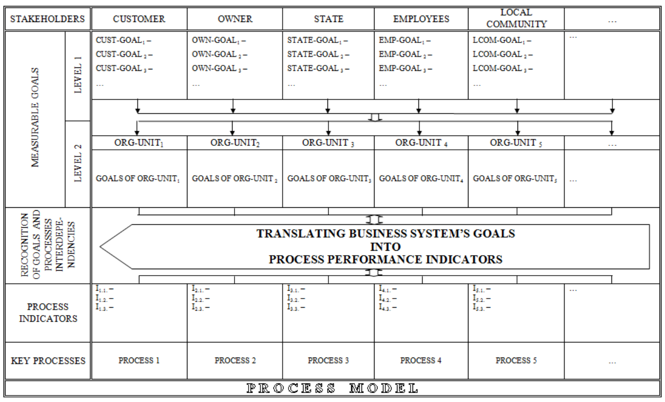

Figure 1. Procedure for translating the business system's goals in process performance indicators (Radović at al, 2012, p.129)

4.2. Results

The proposed model has been applied in 31 companies, which have been the subject of case study. Among 31 companies, 9 were small companies (29%) with less than 50 employees, 12 were medium companies (38,7%) and 10 (32,3%) were large companies (with more then 250 employees) . When it comes to business field that the company is operating in, 13 (41,9%) were service oriented, 14 (45,2%) were manufacturing companies, while only 4 (12,9%) were operating both in service and manufacturing industry.

The stakeholders, that are recognized in those companies are: customers, owner, state, local community, employees and suppliers.

Detailed overview of the companies as well as the results of applying the model in those companies are shown in (Simeunović, 2015).

5. DISCUSSION

Proposed model was applied in 31 companies in Serbia, and on the basis of the collected data, the universal list of the highest level goals (that are defined according to stakeholders' requirements) was obtained. The list include a total of 37 different goals that are defined (in the same or similar way) in these companies. Golas are given in a general form, and their quantification, ie closer specification is done for each organization in particular. Proposal of the list of goals, based on case studies, and the percentage of companies that defined these goals are given in (Simeunović, 2015).

Based on the abovementioned, the sub-hypotheses H1 and H2 were confirmed.

After defining the universal list of the highest level goals, these goals were, for each company, decomposed to the goals of the organizational units, which are responsible for accopmlishing the highest level goals. A total of 32 goals of organizational units were identified.

Furthermore, the key processes (that contribute to realization of these goals) were recognized in each company. All these key processes were then categorized, resulting in the list of 19 key processes (in general form). Performing those processes enables achievement of predefined goals in all companies (from case study). Detailed review of these processes can be found in (Simeunović, 2015).

Based on the abovementioned, the sub-hypothesis H3 was confirmed.

For each process, the process performance indicators (one or more), which will be measured and monitored, were defined. Based on data on process performance indicators collected in all the companies (which were the subject of case studiy), the universal list of process performance indicators was defined. Based of that list, each company, regardless of the activeness, form of ownership, size and form of organization, may select its own set of indicators, in order to monitor and assess the achievement of goals. The list includes 172 process performance indicators, shown in (Simeunović, 2015).

Based on the abovementioned, the sub-hypotheses H4 and H5 were confirmed.

Confirming sub-hypotheses H1-H5, the general research hypothesis is accepted:

H0. By defining a universal set of goals at the highest level of the organization, a universal set of goals of organizational units and the universal set of process performance indicators, the PM system flexibility could be improved.

6. GPI PROCESS PERFORMANSE MEASUREMENT MODEL

Based on research, the initial PM model was improved, and the improved version of model is named GPI process performance measurement model. The model was named as the acronym of three key words that form its structure: Goals, Processes and Indicators.

GPI model can be used in its narrower and broader version. Narrower version of GPI model allows application of model just as it is, without any changes (emphasizes flexibility), while broader version of the model implies its adaptation to the needs of concrete business system (emphasizes adaptability). Since the topic of the paper is PM models flexibility, the narrower version of GPI model will only be shown.

In the model, the highest level goals of the organization are predefined, as well as the goals of organization units, key processes and their performance indicators. The links between them are determined too. The model is specified based on case study research and it can be used (as such) in every business system, which means that it is extremely flexible.

Based on case study, the highest level goals of each company were analyzed, and the universal list of these goals, which contains a total of 12 different goals was defined. The list is shown in Table 2.

Table 2: Universal list of the highest levell goals, and theirs labels (Simeunović, 2015)

RB	Label	Goal
1	CKO_1	Improve/maintain product/service quality
2	CKO_2	Cut short/fulfill deadlines
3	CKO_3	Reduce/keep product/service price
4	CVL_1	Increase profit
5	CVL_2	Develop bussines
6	CZA_1	Increase wages
7	CZA_2	Improve work conditions
8	CZA_3	Provide training for staff
9	CDO_1	Regularly pay payables to suppliers
10	$CDR\text{-}LZ_1$	Regularly pay taxes and contributions
11	$CDR\text{-}LZ_2$	Increase employment/decrease unemploymenti
12	$CDR\text{-}LZ_3$	Protect environment/meet environmental requirements

It was also determined that the achievement of the defined goals can be monitored with a total of 20 process performance indicators. It is important to note that key processes should always be identified first, and then the indicators of these processes. But, considering that the final result (output) of model is the direct link betveen the highest level goals and process performance indicators, in Table 3, process performance indicators were first presented, and then the key processes in which these indicators should be measured.

Table 3: Process performance indicators, their labels and key processes (Simeunović, 2015)

RB	Code	Proces performance indicator	Key Process
1	IKV_2	The waste percentage	Product production / service provision
2	IKV_3	The percentage of non-compliant pieces	Product production / service provision
3	IKV_{21}	Percentage/number of (non)compliance with environmental requirements	Quality service provision / Quality Control
4	IKV_{24}	Number of corrective measures	Quality service provision / Quality Control
5	IKV_{31}	The complaint rate	Sales service provision; Collection and processing of complaints
6	IPR_1	(Annual) production volume	Product production / service provision
7	ITR_1	Total (annual) production costs	Product production / service provision
8	ITR_2	The cost per unit of product/service	Product production / service provision
9	IRO_{15}	The percentage of on-time deliveries	Product production / service provision; Providing services logistics / warehousing / transport; Providing services procurement
10	IRO_{16}	(Average) delivery time	Product production / service provision; Providing services logistics / warehousing / transport; Providing services procurement
11	IRZ_1	The number of new types of products or services (per year)	Product design and development; R&D service provision
12	IRD_1	The total number of employees of a particular profession (in a particular organizational unit)	HR services provision / training and professional development
13	IRD_7	The number of workers who have attended training/seminar/specialization	HR services provision / training and professional development
14	IRD_8	Number of organized seminars / trainings (per year / on a particular topic)	HR services provision / training and professional development
15	IRD_{15}	The rate of employee satisfaction with working conditions	HR services provision / training and professional development
16	IPD_2	(Annual) sales volume	Sales service provision
17	IMA_1	The market share (domestic or EU)	Marketing service provision/Market Research
18	IMA_{11}	(New) customer acquisition rate	Marketing service provision/Market Research
19	IFI_6	The amount of unpaid liabilities / unpaid net earnings	Financial service provision/ Payment process
20	IFI_7	Amount of (un)paid liabilities on time	Financial service provision/ Payment process

The names of key processes are generalized, and for operational usage of model, it is preferred to adapt their names to the specific company.

Interdependence of the the highest level goals and process performance indicators can be represented as follows (Simeunović, 2015):

CKO_1=f (IKV_{31}, IKV_2, IKV_{24}, IKV_3)
CKO_2=f (IRO_{16}, IRO_{15})
CKO_3=f (ITR_1, IKV_2, ITR_2)

CVL_1= f(all defined process performance indicators)
CVL_2 = f (IRZ_1, IMA_1, IPR_1, IPD_2, IMA_{11})

CZA_1=f(all defined process performance indicators)
CZA_2= f (IRD_8, IRD_{15})
CZA_3=f(IRD_8, IRD_7)

CDO_1=f(IFI_6, IFI_7)

CDR-LZ_1=f(all defined process performance indicators)
CDR-LZ_2 = f (IMA_1, IRD_1, IPR_1, IRZ_1)
CDR-LZ_3=f(IKV_{21})

7. CONCLUSION

Since a contemporary management of the organization involves management of its processes, the achievement of organization's goals depends on the success of its processes. The success of the process, ie their ability to meet organizational goals, is measured by using key performance indicators.

Analysis of the existing PM models showed that only a few of them has a certain flexibility, ie that is applicable to all organizations, without major changes. However, these models are applicable only at process level (not at whole organization level). Some PM models can be applied in different type of organizations, but only to a certain level, ie performance indicators must be defined again for each organization, and that's time consuming, so they can not be considered as fully flexible models.

Accordingly, the new GPI process performance measurement model is proposed, which is based on process management. This model starts from the highest level goals (that are defined according to stakeholders' requirements), decomposes them on the goals of organizational units and links them to the key processes performance indicators. In this way, GPI model allows specification of a universal set of the highest level goals and universal set of process performance indicators, thereby increasing the model flexibility.

In order to verify validity of the model, a case study research was done. Proposed model was tested at 31 cases, i.e. in 31 organization that manage their processes. Research was conducted from October 2011 to February 2013. Based on the study findings, previously conceptualized model is improved.

The narrower version of GPI model, which is presented in the paper, is applicable in each company, regardless of the activeness, form of ownership, size and form of organization. In the model, the highest level goals of the organization are predefined, as well as the goals of organization units, key processes and their performance indicators. The links between them are determined too. The model is specified based on case study research and it can be used (as such) in every business system, which means that it is extremely flexible.

Results of research and proposed GPI model create the basis for better and easier performance management, but also for further research in this area.

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DETERMINATION OF FAILURE DISTRIBUTION PARAMETERS FOR BANBURY MACHINE

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Abstract: *Planning, conducting and control of maintenance activities enable to the highest level of availability of manufacturing machines. Maintenance is a set of activities that carry out to keep a system or equipment in operation. Maintenance activities are basically divided into two types as preventive maintenance and corrective maintenance. Failure distribution of machines and equipment has to be known for planning space parts, labor and tools. This can be determined by using failure data and suitable statistical method. In this study, failure distribution parameters of banbury machine were determined by using real failure data. Applied method was shown for the equipment which is vitally important.*

Keywords*: failure distribution parameters, maintenance, banbury machine, weibull distribution, maximum likelihood estimation*

1. INTRODUCTION

Tyre manufacturing process should be formed and managed properly in order to ensure completion of the process in time. The maintenance planning of Banbury machines used in tyre manufacturing should be arranged such that availability is always at a maximum level. In addition, spare part, labor and equipment planning should also be carried out properly so that maintenance activities can be carried out as planned. It is possible to do this for preventive maintenance activities since the times have already been scheduled. However, the same is not true for corrective maintenance activities. Because it is not known when there will be a failure. If the past failure data are available for the system or component for which corrective maintenance activities will be carried out, this uncertainty can be decreased significantly. Since past failure data will fit a certain statistical distribution and if the parameter values for this distribution are determined then it is possible to carry out spare part, labor and equipment planning based on the failure time estimations.

2. LITERATURE REVIEW

Zeytinoglu (2009) conducted a study to determine the weibull distribution parameters for a material that is being used as the printing unit of a photocopier. Graphic method, least squares method, maximum likelihood method and moment method were used for parameter estimation. At the end of the study, results of methods were compared. Kurban, Kantar and Hocaoglu (2009) used weibull distribution for analyzing wind speed and wind power. Moment method was used for parameter estimation. Razali and Al-Wakeel (2013) used mixture of two or three parameters Weibull distributions for fitting failure times. Maximum likelihood estimation method was used for estimating the parameters. Kurz, Lewitschnig and Pilz (2014) carried out a study to determine the weibull distribution parameters by using advanced Bayesian model. Time-to-failure and discrete failure count data belongs to burn in period were investigated for parameter estimation. Tan (2008) developed a new approach for two parameter weibull distribution parameter estimation to cope with interval data. Maximum likelihood estimation method was used for parameter estimation. Demonstration and validation of the approach were shown with data generated by Monte Carlo simulations. Zhang and Dwight (2013) performed a study for choosing an optimal model for failure data analysis by using graphical approach. Different shapes of plots on Weibull probability paper were created by using data. Selection of optimal model for failure data analysis is based on the shapes of the fitting plots. Abbasi, Jahromi, Arkat and Hosseinkouchack (2006) conducted a study to determine the weibull distribution parameters by using simulated annealing algorithm. Hung and Chang (2011) carried out a study for determining the mixed-weibull distribution parameters. Moment method and regularization type of fuzzy clustering algorithm were used for parameter estimation. Chu and Ke (2012) performed a study to determine the weibull distribution parameters. Least squares method and maximum likelihood estimation method were used for parameter estimation. Performance of two methods was evaluated via numerical simulation. Kaplan (2016) used weibull distribution and rayleigh distribution for analyzing wind energy potential of Osmaniye city. Moment method and graphical method were used for parameter estimation.

3. MAINTENANCE

Maintenance covers all the actions carried out to repair or to ensure that a unit, part or equipment continues to work under certain conditions (Dhillon, 2002). With regard to production systems, maintenance activities are those that are carried out so that all production systems or certain equipment are in working order. This definition shows that maintenance function covers not only intervention to a failure but also proactive tasks such as routine inspection, preventive maintenance, replacement and condition monitoring.
Various decisions related with specifications, purchasing, planning, operating, performance evaluation, development, replacement and scrapping are made for every stage of the life curves of various technical systems such as factories, machinery, equipment or plants within the scope of maintenance management. Maintenance management is thus the management of physical assets based on this wide perspective (Köksal, 2007).

3.1. Corrective Maintenance

It would be wiser to explain the concept of failure prior to corrective maintenance. Failure is the stopping of a system or the decrease in production rate and/or quality due to an unpreventable reason. In this method, intervention or repair is carried out after the failure. The machine or machines stop until repair. Maintenance crew and maintenance workshop strive to start the production system in the shortest possible time. Spare machines or spare parts are put into use if any so that the line continues working.
In corrective maintenance, a machine does not go through maintenance unless there is a failure. Other maintenance works are carried out with the repair when there is a failure. Most of the repairs are quick-fixes that are made to ensure that the failed part is repaired and that the machine continues to operate. These companies operate as minimum repair and work with professional maintenance companies for large maintenance-overhaul works. This is a management approach that minimizes maintenance crew and material costs (Köksal, 2007).
Corrective maintenance is observed most frequently in the following cases (Köksal, 2007):

- Small workshops with general purpose universal workbenches,
- Facilities that are planned to be sold out because they have become outdated or idle due to the changes in the market,
- In cases when there is more than one spare equipment in the facility (e.g. when there are three parallel connected equipment and one of them fails)
- Activities that support main production (forklift, compressor and similar equipment)

3.2. Preventive Maintenance

In this method, the machinery equipment, buildings or facilities go through inspection at certain periods and before any failure arises and protective activities such as machinery adjustment, cleaning, part replacement, painting and other minor repairs are carried out if necessary. It is a preventive activity (Köksal, 2007). Preventive maintenance should have the following properties (Köksal, 2007):

- Oiling: An oiling program should be included in all preventive maintenance policies. It should be carried out with trained personnel.
- Inspection: The condition of machinery equipment is under constant control with regular inspections. It should be decided to stop the machine for maintenance prior to the arising of any changes due to heat, vibration or wear.
- Programmed power off or maintenance: It is the planning of short or long term general maintenance or power off maintenance work. Transfer workbenches, heat treatment ovens, presses and reactors for short term.

The preventive maintenance activities listed above are generally carried out outside the production hours so that the operation is not stopped.

4. FAILURE DISTRIBUTIONS

When the failures in a system or component are recorded, it will be observed that the failure data fit a certain statistical distribution. When the current failure data are evaluated statistically, it will fit a distribution and the parameters of that distribution will take on values. The parameter values of the distribution will yield the

failure distribution of the related system or component. Based on this information, failure times will be estimated and maintenance planning will be made.
Even though there are many models used for failure distribution, the most widely used are weibull distribution, exponential distribution and normal distribution.

4.1. Weibull Distributions

Weibull distribution was put forth by Waloddi Weibull in 1951 in order to estimate the life times of machines. Today, it is used in the statistical models that are part of the science of engineering as well as in life data analysis. Weibull distribution is widely used in models that will be set up for the data set related with failure ratios which in some cases has a Rayleigh or exponential distribution based on the values that the shape parameter takes.
In general, the Weibull distribution is one that has a scale and shape parameter. The two parameter weibull probability density function is given below:

$$f(T) = \frac{\beta}{\eta}\left(\frac{T}{\eta}\right)^{\beta-1} exp\left[-\left(\frac{T}{\eta}\right)^{\beta}\right] \quad (1)$$

Here, $f(T) \geq 0$, $T \geq 0$, $\beta > 0$, $\eta > 0$ and β is the shape parameter, η is the scale parameter. The two parameter weibull cumulative distribution is given below:

$$F(T) = 1 - exp\left[-\left(\frac{T}{\eta}\right)^{\beta}\right] \quad (2)$$

One of the parameters of the Weibull distribution is the shape parameter and the reason for various different distributions is the value that the shape parameter takes. Failure rates increase over time when the slope value ranges between 0 and 1, that is when $0 < \beta < 1$. As a special case, when $\beta = 1$, "$f(T)=1/\eta \ \ exp(-T/\eta)$" distribution is an exponential distribution. Here, "$1/\eta \ = \lambda$" represents the failure rate. When $\beta = 2$, it becomes the rayleigh distribution (Zeytinoğlu, 2009).

5. DETERMINING THE PARAMETER VALUES OF THE DISTRIBUTION

Statistical models mostly depend on data for estimations. The accuracy of any estimation depends on the completeness and quality of the data to be used. A good estimation can be made when a good data set is combined with the right model. The data that we will use when determining the parameter values of failure distribution may not be complete, they may include some uncertainties. Thus, we can classify the data used for analysis as complete data and censored data.

5.1. Complete Data

Complete data means that every sample unit has been observed and is known. For example, if we are testing five units and if all five of these units have failed during testing then it means we have complete data (http://reliawiki.org/index.php/Life_Data_Classification, 03.06.2013).

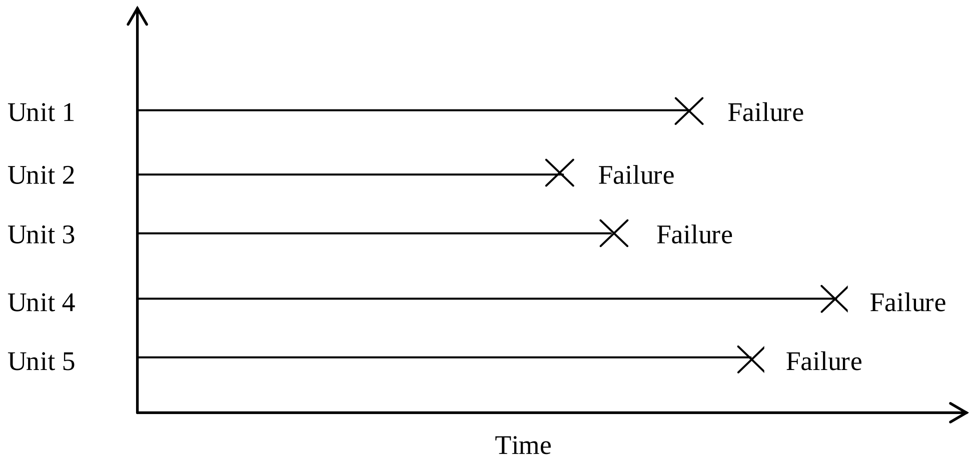

Figure 1: Complete Data

5.2. Censored Data

In many cases, not all sample units fail during testing or there may be instances when we cannot detect the exact time of failure. Such data are known as censored data. There are three types of censored data: right censored, interval censored and left censored (http://reliawiki.org/index.php/Life_Data_Classification, 03.06.2013).

5.2.1. Right Censored Data

It is the most common among censored data. For example, if we have tested five units and if only three of these units have failed until the end of the test, it means we have two right censored data (http://reliawiki.org/index.php/Life_Data_Classification, 03.06.2013).

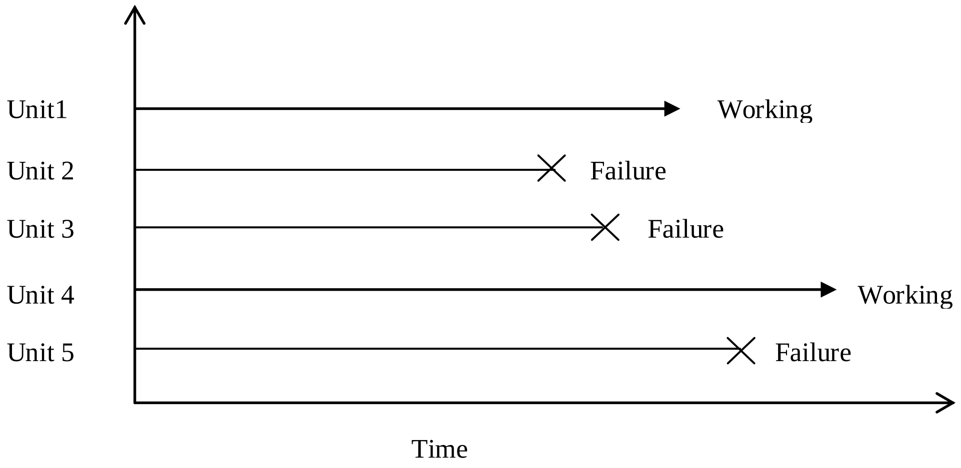

Figure 2: Right censored data

5.2.2. Interval Censored Data

Interval censored data represents the uncertainty regarding the time of failure of the tested unit. Thus, it is not certain when the unit has failed. This is observed in cases when the related unit is not under constant monitoring. For example, if we are testing 5 units and we observe these units every 100 hours, we can only know if the units failed between the observation times. If we are to give a more detailed explanation; if we observe that the unit is functioning at the end of the first 100 hours and that it has failed at the end of the second 100 hours, we can state that this unit has failed during 100-200 hours (http://reliawiki.org/index.php/Life_Data_Classification, 03.06.2013).

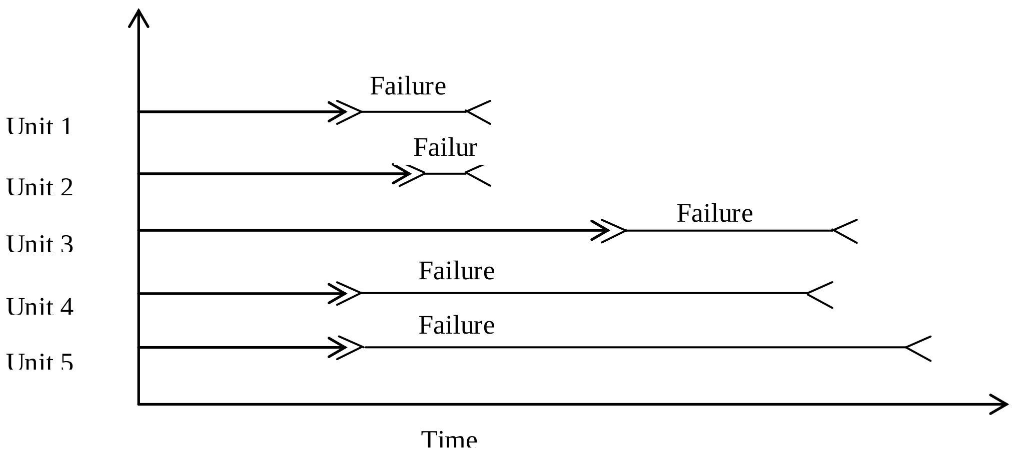

Figure 3: Interval censored data

5.2.3. Left Censored Data

For left censored data, we can know if the tested units have failed before a certain time or not. For example, we can state that the unit has failed before 100 hours, however we cannot give an exact time. In other words, this means that the unit has failed at some point in the 0-100 hour interval (http://reliawiki.org/index.php/Life_Data_Classification, 03.06.2013).

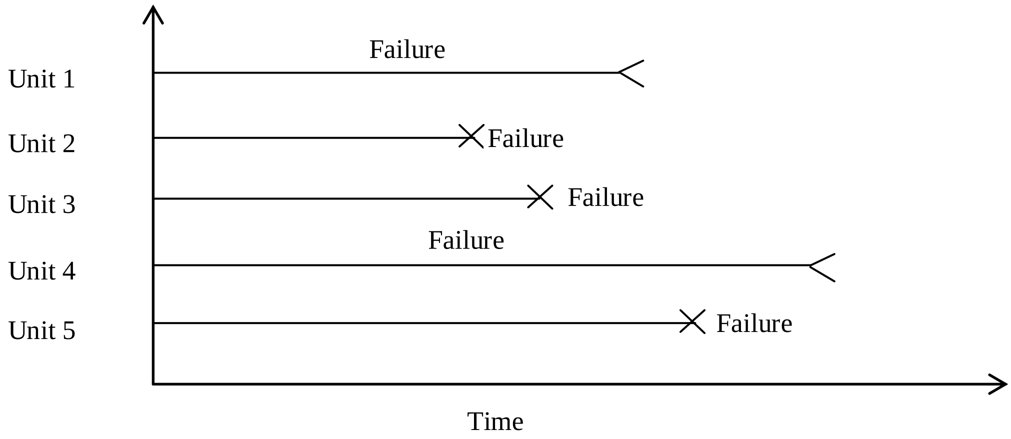

Figure 4: Left censored data

6. APPLICATION

Failures of banbury machines used in tyre manufacturing have been handled in the application. Banbury machines play an important role for tyre manufacturing process. Indeed, banbury machines failures significantly effect it.

Maximum likelihood estimation method, probability plotting, least squares method and moment method can be listed as methods used to estimate the parameter values of failure distribution. In this study, banbury machines failure data were used to calculate the weibull distribution parameter values using Minitab software in accordance with the maximum likelihood estimation method.

6.1. Maximum Likelihood Estimation Method

k and c are shape and scale parameters respectively in Weibull distribution. Maximum likelihood estimation is one of the methods used to calculate these parameters. Failure data comprise a set of n elements such as $v_1, v_2, \dots\dots\dots\dots. v_n$ when using this method. The probability of $V = v_i$ in the observation is proportional with $f(v_i; k, c)$. Similarly, the probability of events occurring can be expressed as $V = v_1 \dots \dots V = v_n$. Since the events are independent of each other, the probability of events $L = \prod_1^n, \dots\dots. V = v_n$ occurring can be written as such:

$$L = \prod_1^n f(v_i; k, c) \tag{3}$$

Scale parameter;

$$c = \left[\frac{\sum_{i=1}^{n}(v_i)^k}{n}\right]^{\frac{1}{k}} \tag{4}$$

Shape parameter;

$$k = \left[\frac{\sum_{i=1}^{n} v_i^k In(v_i)}{\sum_{i=1}^{n} v_i^k} - \frac{\sum_{i=1}^{n} In(v_i)}{n}\right]^{-1} \tag{5}$$

is obtained with these equations.
It is difficult to solve the equation since it is iterative. Hence, it is not a method used before modern technology (Akdag and Guler, 2008).

6.2. Determination of Failure Distribution Parameters

The analysis was conducted with dip tank failure data of banbury machine which is used in tyre manufacturing. Failures of dip tank are of crucial importance for banbury machine because they affect running of the system substantially. Banbury machine has a dip tank. Failure data of the dip tank was recorded for 365 days. 35 dip tank failures are available during the analysis period Thus; we have 35 complete data.
Failure data of the dip tank have been entered in the Minitab software and the weibull distribution parameters for it have been determined. "Failure" expression was used for complete data while entering the failure data into the software. Parameter values for the two parameter weibull distribution have been determined as β=0,287 and η=38,8481 in hours. In addition, the mean time to failure value for the dip tank has been determined approximately as 440 hours. In other words, the average life of it is 440 hours. The screenshot of the software used for analysis has been given below:

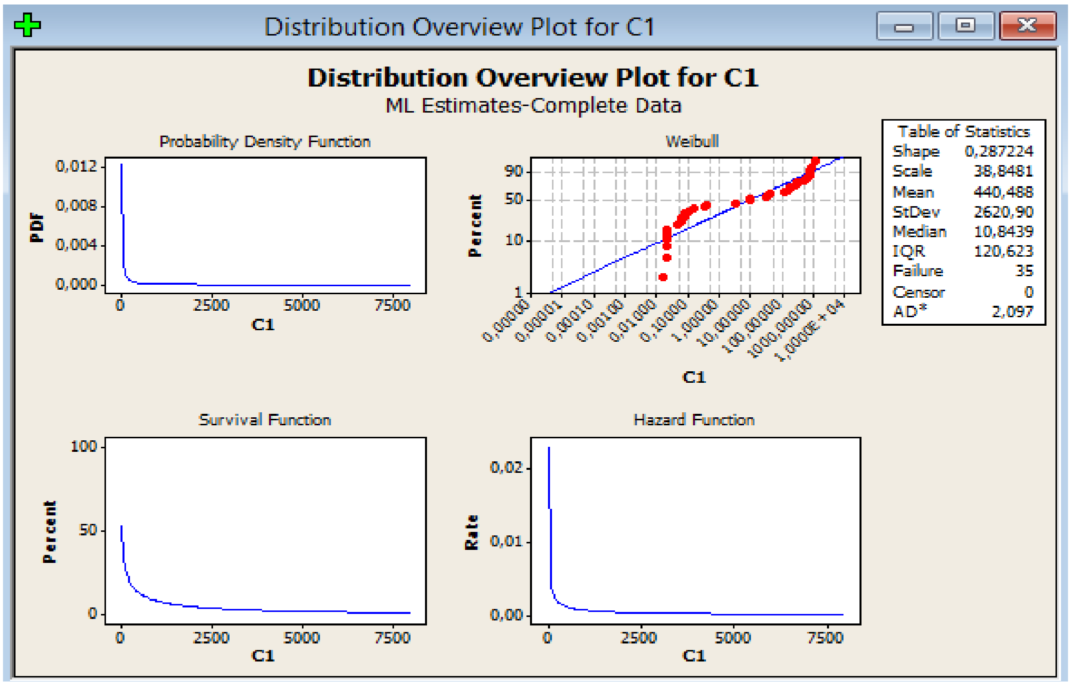

Figure 5: Screenshot of analysis

7. CONCLUSION

Planning of spare parts, labor and equipment to be used in maintenance activities has to be carried out accurately in order to ensure that the planning activities are executed in a planned manner. It is possible to do this for preventive maintenances, because the maintenance times are predetermined. However, the maintenance time is not certain for corrective maintenance activities since it is not known beforehand when a failure will arise.
In this study, failure data of banbury machine used in tyre manufacturing have been used to determine the failure distribution parameters via Minitab software in accordance with the maximum likelihood estimation method. In this way, failure times will be estimated and corrective maintenances will be carried out in proper manner. Since the spare part, labor and equipment planning will be carried out in accordance with this estimated value.

8. FUTURE WORK

While determining the failure distribution parameters, failure data can include some uncertainties. In other words, left censored data, interval censored data and right censored data can be available in data set. Therefore, effects of censored data for failure distribution parameters can be investigated in future works.

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OVERALL ORGANIZATIONAL PERFORMANCE: A NOTE ON FIRMS OPERATING IN THE WESTERN BALKANS REGION

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Abstract: *Most firms in the Western Balkans region manage only some portion of their performances due to the lack of understanding of the overall organizational performance concept. The result is an empty space that represents a potentially tremendous opportunity for managers wishing to fill the gap between their firms' current and desired level of performance. The paper starts with a theoretical background aimed to increase the practitioners' understanding of performance systems and management concept by integrating three levels of organizational performances into one comprehensive framework. This literature review sets the stage for empirical investigation conducted in 22 firms in the 5-years period that showed that, even though all the firms from the sample have some sort of performance system at strategic level, operational and individual level of performance are mainly not covered. Therefore, most of the firms are not in the position to effectively and systematically manage their performances, which is a necessary condition for their long term development. In order to remedy this situation, management will have to increase the awareness about the concept of the overall organizational performance in their firms, develop a proper performance management methodology, and bridge the gap in knowledge and skills related to performance management that resides in their employees.*

Keywords*: performance management, process, indicator, measurement, Western Balkans*

1. INTRODUCTION

Survival of firms depends on their overall performance. It is no longer viable to focus on some specific aspect of performance, such as production performance, financial performance, or sales performance. In order to stay competitive over the long run, firms must take a much broader view. They have to start tackling the performance issue holistically. More specifically, they need to grasp the complexity of their business, take a multidimensional perspective on performance, define various measures, conduct measurements, acquire and analyze the results, and perform specific actions accordingly. Thus, a lot of work is ahead of managers willing to manage the overall performance of their firms.

However, one must recognize the difficulties on this journey. One of the biggest roadblocks is the fact that it is not possible to measure social phenomena, such as those considering firms and their overall performances, with anything close to accuracy that characterizes the field of science. In line with this argument, Wholey (1996) states that performance is not an objective reality waiting to be measured and evaluated, but rather a socially constructed reality that exists in people's minds. Therefore, designing and implementing a performance management system within a firm is not an easy task. It is a very complex and time consuming effort that requires both imagination and analytical skills.

Considering these facts, it is no wonder Taticchi (2008) claims that interest in performance management has notably increased over the last 20 years (cited in Taticchi, Tonelli & Cagnazzo, 2010). Nevertheless, even though results of impact of this increased interest are mixed, it might be argued that its practical implications have not yet reached the benefits expected. For example, the results of a survey of 278 organizations from 15 countries, out of which about two-thirds are multinational corporations, showed that around 91% of them have established some form of performance management system. Survey findings revealed that organizations with formal and systematic performance management systems are 51% more likely to outperform their competitors regarding financial outcomes and 41% regarding additional outcomes including customer satisfaction, employee retention, and other important metrics (Casio, 2006). On the other hand, a public survey conducted recently by Deloitte revealed that more than half of the executives questioned (58%) believe that their current performance management approach drives neither employee engagement nor high performance (Buckingham & Goodall, 2015). These findings show that, even though some level of success with performance systems implementation is evident, current performance management systems have to be reexamined and modified in order to serve their purpose in a more holistic manner.

The purpose of this paper is to provide evidence to the managers in the Western Balkans about the existence of a wide gap between their practice (performance systems currently employed by their firms) and the overall organizational performance system. Therefore, its goal is twofold: (1) to depict the framework for overall organizational performance system in order to help managers understand this concept and benefits of its implementation (achieving this goal might be of interest to practitioners working worldwide), and (2) to set out to explore the current conditions of performance management in firms operating in Western Balkans region (the part of paper dedicated to this goal might be more interesting to practitioners working in Western Balkans). The paper starts with theoretical background in which the concept of performance management and overall organizational performance system is explained. The next part depicts the research conducted in firms operating in Serbia, FYR Macedonia, and Bosnia and Herzegovina between 2011 and 2015, as well as its results. The section considering practical guidelines regarding implementation of an overall organizational performance system in the firms follows. The paper ends with conclusion remarks.

2. THEORETICAL BACKGROUND

Firm performance indicates the quality of the firm's continuous co-alignment with the environment (Chakravarthy, 1986). On the other hand, performance management is seen as a tool that helps management improve organizational performance (Aguinis & Pierce, 2008) by providing them more control over a firm, which is in line with de Waal's (2010) argument that there is a clear and strong relation between organizational performance and the attention given to management control.

Performance management system may be regarded as a set of formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities (Simons, 2000). This system focuses on conveying financial and non-financial information that influence decision making and managerial action (de Wall, 2010). It is a balanced and dynamic system that enables support of decision-making processes by gathering, elaborating and analyzing information (Neely, Adams & Kennerley, 2002). The term "balance" refers to the need of using different perspectives and measures with both leading and lagging indicators that, tied together, provide a holistic view of an organization (Kaplan and Norton, 1992; Kaplan and Norton, 1996). On the other hand, "dynamicity" refers to the need of developing a system that continuously monitors the internal and external context and reviews objectives and priorities (Bititci et al., 2000).

Performance-based management includes developing a reasonable level of agreement on goals and strategies for achieving goals, as well as developing performance measurement systems that provide data that are sufficiently complete, accurate, and consistent to document performance and support decision making (Wholey, 1999). Performance may focus on inputs (money, assets, workforce, etc.), processes itself or some of their parts or activities (lead time, cycle time, etc.), or outputs (products or services delivered to the customers). It may focus on a variety of complex indicators that put different indicators in some sort of relations, such as efficiency or productivity which relate output to input. Performance may also focus on intermediate outcomes such as client satisfaction or end outcomes such as environmental quality or health status (Wholey, 1999). On the other hand, Simons (2000) argues that performance management systems cannot be designed without taking into consideration human behavior. Thus, it is not enough to observe only the hard elements of performances, i.e. what is being done, but also the soft components, i.e. the manner in which it is done.

That being said, no wonder that in the late 1980s and early 1990s dissatisfaction with traditional backward looking accounting based performance measurement systems led to the development of more complex, holistic and balanced measurement frameworks (Bourne et al., 2000). The need for an integrated approach to performance management based on systems thinking (Senge, 1990) was recognized. Instead of an isolated approach to one dimension of performance, the focal point became an integration of all components of the system and mapping the relationships between them (Brudan, 2010).

In order to secure its viability over the long run, the majority of firms need a management system based on overall organizational performance. Lawrence and Lorsch (1967) further elaborate this argument by stating that "it is clear that total organizational performance is... related to achieving the degree of integration between subsystems required for the overall organizational task of coping with the external environment." (p. 11) Therefore, the task of designing, implementing and managing overall organizational performance system seems quintessential for the success of any firm.

Overall organizational performance system is a very complex network of various indicators organized into three basic levels: strategic, operational and individual (cf. Brudan, 2010). At strategic level, performance management deals with the achievement of overall organizational goals. This level is crucial for the long term adaptation to the environment, especially in situations in which management ought to pay attention to a large number of variables in the environment and their volatile dynamics (cf. Stefanović, Prokić & Vujović, 2012). Performance management at operational level covers end-to-end processes, i.e. the manner in which the value is being created for the end-users. This level acknowledges the processes as the driving force of any firm (Hammer & Champy, 1993), while adopting the customer's point of view (Davenport, 1994). The third level of performance is oriented on individuals. It covers the manner in which their day-to-day activities are being performed and the results achieved.

These three levels of performance ought to be seen as inextricably intertwined parts of the same system, even though in practice this is rarely the case. "Practice shows that communication and integration between the three levels of organizational performance is limited... Management does not see performance management as an integrated discipline used at various organizational levels, but as a subcomponent of strategic, operational and HR management respectively. An integrated approach, linking together all levels of performance management, becomes a necessity for both research and practice to facilitate the understanding and usage of performance management systems... This proposed integrated view to performance management has the potential to assist individuals and organizations to better understand and align these levels and create a complete, holistic picture of performance that outlines the relationship between organizational and individual performance." (Brudan, 2010, pp. 117-119). Having in mind the importance of having one integrated and overall performance system in place, we will elaborate on each of the three performance levels.

2.1. Strategic performance level

Strategic level emphasizes the firm's relationships with its environment and the basic "skeleton" of the major functions that comprise the firm (Rummler & Brache, 2013). In other words, strategic level is focused on strategic goals, i.e. the goals covering the whole firm as a part of its business strategy. These goals are then broken down to subgoals for each function. Only by taking a holistic stand and viewing the firm as a whole, its subgoals will not permit the optimization of the functional silos. Therefore, each subgoal ought to be derived from one of the strategic goals and be aligned with it.

The performances at this level are being measured by the percentage of achievement of strategic goals and subgoals. Only after the measurement results are obtained and analyzed, the discussion regarding further actions may start. Of course, this discussion must incorporate the results obtained from the other two levels of performance as well. Considering strategic level solely will not provide comprehensive information, which may jeopardize the effectiveness of further actions.

Strategic goals and accompanying functional subgoals may only be achieved through the hard work being done by every employee of the firm. In other words, strategic performance level needs to be integrated with other levels of performance in order to establish and manage the overall performance management system. Only in this way will strategic performance system gain its full relevance.

2.2. Operational performance level

Focusing on strategic level performance by itself will not provide a significant level of understanding of how the firm actually works. For this to happen, on must probe deeper into the firm's "skeleton". This deeper level will show the processes, which may be understood as the manner in which a firm does its work, i.e. the set of activities it pursues to accomplish a particular objective for a particular customer, either internal or external (Davenport, 2005). Operational performance level relates process performance and the customer satisfaction level resulting from it (Davenport, 1994). Taking the process standpoint in firms is likely to yield certain benefits in terms of the overall performance (Davenport & Stoddard, 1994).

Rummler and Brache (2013) argue that a firm is only as effective as its processes. Therefore, operational performance level shows whether the work is done effectively and efficiently enough. The first step on this level is to identify all the processes being run within a firm and the relevant process performance indicators. These indicators are derived either from process goals or from the means of achieving these goals, i.e. subgoals. Each of these goals ought to be congruent with enterprise wide goals, take into account the behavior of the competitors and, last but not least, be in line with process stakeholders' interests. It is very important to emphasize that process performance represents a degree of stakeholder satisfaction, which is why process performance measurement ought to be focused on those individuals who have an interest in the business process. In order to develop this stakeholder-driven performance measurement system, stakeholders of the process have to be identified and their process-relevant goals clarified. Each group of stakeholders needs to be represented by an aspect or dimension of performance (Kueng, 2000).

Measuring the process performance is critical for process improvement and excellent process management is based on suitable performance measures (cf. Chiou-Shuei, 2014; Crandon & Merchant, 2006). Once there is a reasonable level of agreement on the meaning of performance, managers can obtain information on key aspects of process performance through performance measurement, that is, the periodic measurement of specific inputs, activities, outputs, intermediate outcomes, or end outcomes. Performance measurement includes both the collection and analysis of numerical data and less formal assessment of performance such as narrative assessment of the extent of progress toward defined goals (Wholey, 1999). "The main objective of process performance management system is to provide comprehensive and timely information on the performance of business processes. This information can be used to communicate goals and current performance of a business process directly to the process team, to improve resource allocation and process output regarding quantity and quality, to give early warning signals, to make a diagnosis of the weaknesses of a business process, to decide whether corrective actions are needed and to assess the impact of actions taken." (Kueng, 2000, p. 72).

2.3. Individual performance level

Stopping at the operational level would hinder the understanding of performance on the most granular level: an employee and the work he or she performs. Rummler and Brache (2013) argue that "performance can be improved only if jobs and performers are analyzed in an overall performance context." (p. 62) Therefore, focusing on each individual within a firm is an essential task if one wants to gain a holistic view on performance.

Performance management system on the level of employees can be based on a consideration of behavior (how work is being done) or results (outcomes of work). Of course, combination of both is possible as well (Aguinis & Pierce, 2008). When it comes to work, Rummler and Brache (2013) advocate so-called "Human Performance System" (HPS), which may be one of the best approaches for managing the performance on individual level. TPS contains the following elements (Rummler & Brache, 2013): (1) input in terms of task support, (2) performer with its skills, knowledge and capacity, (3) output in terms of performance specifications, (4) consequences of reaching or not reaching the desired performance, and (5) feedback in terms of information about the performer's performance. Each of these elements is being permanently assessed for each employee within a firm.

TPS approach implicitly states that performance problems occurring at individual level may only sometimes be attributed to the employee. Rather, it supports the claim of W. Edwards Deming that employees are responsible for only 15 percent of the problems, and the system for the other 85 percent, which is the responsibility of management (Walton, 1986).

3. RESEARCH METHODOLOGY

The research question this paper is trying to answer is the following: Where do firms operating in the Western Balkans region stand on the road toward implementing the overall organizational performance system? The starting premise that helped authors embark on this journey is that most firms in Serbia and surrounding countries do not have an integrated, holistic system of measuring their performances on a regular basis. Instead, they usually rely on a set of financial measures based on traditional accounting systems. In other words, there is some sort of natural inclination to use the conventional financial data such as: profit, revenue, change in profits, change in revenues, percentage of new products in total sales, and so forth (cf. Lawrence & Lorsh, 1967, p. 25-26). This approach, besides measuring only one dimension of firm performance, focuses on lagging indicators and looks at the performance already achieved, i.e. retroactively. Non-financial aspects of firm performance, such as customer satisfaction or job satisfaction still play a modest role (cf. Eccles, 1991).

Authors' experience is that management tool mostly used in firms operating in Western Balkans is the quality management system certification according to ISO 9001 requirements, which somewhat guarantees that firms identify and execute their business processes in a specified and controlled way. Following this reasoning, the authors seized the opportunity to investigate the current state of the performance systems in firms operating in Western Balkans region during the time one of the authors spent as a management systems consultant and auditor. While running these consultancies and audits, this author acquired the relevant information on numerous firms, which make the majority of the sample collected. The other author has brought his own insights and relevant information from several other firms while working for them. Even though the sample of firms is selected on the "easy to obtain" criterion, thus resulting in the convenience sample, authors believe it is still indicative for the current state of the whole population of firms in the region, which might be confirmed by some other research that would use the representative sample.

This research was carried out in the period between 2011 and 2015 on a sample of 22 firms operating in three countries of the Western Balkans region (Serbia, Bosnia and Herzegovina, and FYR Macedonia). All the firms in the sample have more than 250 employees, which classifies them in the group of large firms according to the current Accounting Law (Službeni glasnik, 2013). Only large firms have been taken into account because their scale allows them to recognize the need and have the necessary resources for implementing performance management systems.

The names of the firms in the sample will remain undisclosed due to confidentiality reasons. However, some details on the structure of the sample ought to be presented. First of all, the number of firms per country (Serbia, Bosnia and Herzegovina, and FYR Macedonia) ought to be revealed. Table 1 shows these numbers.

Table 1: Number of firms per country of their operations

Country of firm's operations	Serbia	Bosnia and Herzegovina	FYR Macedonia	Total number of firms
Number of firms per country	15	2	5	22

Secondly, the relevant data about each firm in the sample have been obtained in one year only during the period 2011-2015. Table 2 indicates from how many firms per year during this period the data have been obtained.

Table 2: Number of firms from which the data have been obtained per year

Year of data collection	2011	2012	2013	2014	2015	Total number of firms
Number of firms per year	5	4	6	1	6	22

Thirdly, there are differences in the number of employees per firm, which is why four categories have been identified and firms have been classified accordingly. This is shown in Table 3.

Table 3: Number of firms per their size in terms of employees

Number of employees	251-500	501-1000	1001-2000	≥2001	Total number of firms
Number of firms in the category	10	8	3	1	22

Finally, the firms in the sample operate in various industries and Table 4 indicates the number of firms per industry. For the purpose of industry classification, NACE classification of economic activities has been used (Eurostat, 2008). Even though some of the firms in the sample perform activities in more than one industry, which means they have more than one code, only the code for principal industry has been used.

Table 4: Number of firms per industry

Section	**Industry title**	**Number of firms**
B	Mining and quarrying	3
C	Manufacturing	10
F	Construction	3
H	Transportation and storage	1
J	Information and communication	2
K	Financial and insurance activities	1
N	Administrative and support services activities	1
P	Education	1
Total number of firms		22

After explaining the manner in which the sample has been obtained, as well as the structure of the sample, the criteria for assessing whether a firm has performance system implemented and at what level the performance is being managed ought to be depicted. In other words, what have the authors done with the collected data? How have they assessed if the firm has implemented performance system at some level?

The criteria for stating that a firm has some form of performance system have been defined as follows:

- Strategic performance level exists if at least 50% of the organizational units at the highest level of hierarchy (usually functions or divisions) have formally defined some sort of metrics (usually in the form of goals and objectives) and take obvious actions toward achieving it.
- Operational performance level exists if at least 50% of all the processes being run in the firm are formally identified and mapped, as well as have some sort of metrics established (usually in the form of KPIs with the associated targets) and obvious actions toward achieving it are being taken.
- Individual performance level exists if for at least 50% of positions (not employees/performers) there is some sort of metrics established that takes into account the performer with his/her behavior (how work is being done) and/or results (outcomes of work), as well as a system surrounding and influencing the performer's performance (adequate inputs, timely feedback, etc.) with the targets defined and obvious actions toward achieving them are being taken.

After depicting the firm sample details and explaining the criteria for identifying whether a firm has a performance system in place at some of the three levels, we will now turn to the results obtained and discuss their implications.

4. RESULTS AND DISCUSSION

Results obtained on the sample of 22 firms operating in three countries in the Western Balkans region are shown in the Table 5.

Table 5: Number of firms with established performance systems per three levels

The level of performance	Strategic	Operational	Individual
Number of firms with established performance system	22	12	1

Even though these results were somewhat expected, what came as a surprise was the fact that more than half of the firms in the sample had some sort of performance system on operational level. Based on their experience, both authors believe that the vast majority of firms operating in Serbia and surrounding countries have not yet completed a proper process identification and mapping, which is a necessary precondition for any kind of process performance system development. In other words, the results obtained at the operational level seemed misleading.

This is why further insights had to be developed. Since it was not possible to go back to the firms from the sample and conduct further investigations, authors have decided to interview some of the people working at those firms. Very quickly, a plausible explanation has been offered.

A number of firms for which the results showed they had operational performance systems in place were actually making those systems only for the purpose of the management systems certifications (e.g., ISO 9001, ISO 14001, BSI OHSAS 18001, etc.). Thus, these systems were actually nonexistent except on paper. Other firms from this sample had these systems in place, only not for the purpose of performance improvement, but rather merely for making more or less complex management reports, while the improvement actions would usually be omitted. It is interesting that the reason for making these reports was often unknown or found in some request from management in the past, but has not been assessed in the light of changing circumstances since then, which indicates the high level of organizational inertia (cf. Stefanović et al., 2014).

This kind of logic for making performance systems resulted in two more negative aspects. First, the performance indicators were not designed in order to reflect the needs of the customer and the accompanying process logic, which is why they were made static, i.e., they were not subjected to the changes in order to reflect the numerous shifts in the environment. Secondly, there was no alignment between the performance indicators on strategic and operational level (the results showed that only one firm had performance system established at individual level). There was not even an alignment between performance indicators on the same level due to the fact that each organizational unit was usually developing its own indicators without taking the perspective of the whole firm or end-to-end processes.

This situation led the authors to the conclusion that true performance systems did not exist at operational level in majority of firms from the sample. Their processes were not being managed systematically through a set of performance indicators. Since performance systems did not exist at individual level either, it became clear that these firms had performance systems established only at the strategic level. On this level, performance indicators were being defined, measurements conducted and improvement actions taken.

5. RECOMMENDATIONS FOR PRACTITIONERS

The results from the investigation depicted in the previous sections show a low level of commitment in the firms operating in Western Balkans toward performance systems design and implementation. Taking this into account, authors can only assume this is attributed to the lack of general understanding of the performance system concept. Therefore, it is clear that something has to be done in order to remedy this situation if these firms are to thrive in the future marketplace.

The path toward designing and implementing the overall performance system is not an easy one. It must start with increasing the level of understanding of all key stakeholders about the concept of performance system and the benefits of its implementation. After all the stakeholders are acquainted with this and their approval is obtained, the work on designing the performance system may begin.

The design effort ought to start on the strategic level with the strategic goals. These goals are then broken down to subgoals for each function or division. After that, the subgoals are treated as targets that must be met by the processes being run within a firm. The processes are being mapped and performance indicators defined, starting from the process targets and moving backwards toward the upstream activities. Of course, each process performance indicator ought to have its own accompanying target in line with the process targets. The next step involves positions in charge of the activities comprising these processes. After identifying the responsibilities of each position within the processes in stake, performance indicators are being defined reflecting the performer’s behavior and results, as well as a system surrounding and influencing the performer's performance (adequate inputs, timely feedback, etc.).

Only the performance system that links performance indicators from the top of a firm to its operating core and spreads throughout an entire organization may provide significant potential for radical performance improvement. Thus, every individual in a firm has to be fully covered by the performance system, which means that performance of every employee will be connected to the performance of every other employee. The resulting network of performances represents the system for measuring and improving the overall organizational performance.

Development, implementation and management of an overall performance system requires: (1) sound measures that ensure the right things are being monitored, (2) a total measurement system, not a collection of unrelated and potentially counterproductive measures, and (3) performance management process that converts the data provided by the measurement system into intelligent action (Rummler & Brache, 2013).

In line with this, it is useful to note that, while designing a performance system in a firm, one must take into account the concepts of business process management (BPM) and business intelligence (BI). BPM is focused on improving a firm performance by managing and optimizing its processes (cf. Panagacos, 2012), while BI brings value to managerial decisions by allowing them to easily identify, collect and interpret large volumes of data (cf. Rud, 2009). These concepts ought to be linked to performance management design from the start: BPM in the area of process identification and mapping, BI in the area of collecting the right data, their measurement and analysis, and BPM again in the process optimization phase. This is being emphasized due to the results of a research conducted in one of our neighboring countries by Vukšić, Bach and Popovič (2013). These results show that the usage of BPM and BI is not orchestrated within the framework of performance management.

5. CONCLUSION

Firms in Western Balkans region, specifically in Serbia, Bosnia and Herzegovina, and FYR Macedonia are on the very beginning of the road toward performance management. Even though some sporadic attempts have been made in this direction, there is a huge amount of work still left to be done. First of all, there is a need to increase the awareness about the concept of the overall organizational performance as a tool for achieving higher states of competitiveness. Secondly, a proper performance development and implementation methodology has to be taken into account and tailored to suit the needs and possibilities of each individual firm. Finally, the gap between required and current level of the employees' knowledge and skills related to performance management ought to be identified and bridged.

Management in firms operating in Western Balkans must embrace the fact that if they wish their firms to continue to grow and develop in the long run, they will have to be able to manage the overall performance of their firms, not just some part of it as has been the case until now.

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IMPROVING EFFICIENCY OF ENGINEER-TO-ORDER OPERATIONS THROUGH LEAN IMPLEMENTATION: EMPIRICAL RESEARCH

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Abstract: *Lean applicability in ETO operations has been questioned by many authors. The results of recent research state that more empirical evidence is needed in order to rule in favor or against lean applicability in ETO environment. This paper presents results of action research, where efficiency of ETO company was improved through lean implementation. Lead times were reduced and delivery reliability was improved, thus adding to the fact that lean can be used for improving efficiency of ETO operations. Lean was implemented through tool-agnostic approach, where implementation was based on laws and principles that define lean, rather than specific tools. This approach provides implementation universality, and takes into account characteristics of specific manufacturing environment.*

Keywords*: engineer-to-order (ETO), lean, efficiency improvement, operational performance, empirical research*

1. INTRODUCTION

The emergence and popularization of lean is considered as one of the most important steps in the development of operations management (see e.g. Hines et al., 2004; Holweg, 2007). Lean can be defined as a continuous effort aimed at eliminating waste and sources of waste. Lean has helped many manufacturing companies around the world to realize significant gains in efficiency (see e.g. Womack et al., 1990; Womack & Jones, 1996; Slović et al., 2015). Still, most examples of efficiency improvement come from manufacturing environment similar to the one in which lean was originally developed in terms of product variety, volumes produced, and component assembly nature (i.e. repeated manufacturing of limited array of similar products in relatively high volumes). Some authors state that, in the future, lean research will abandon traditional manufacturing environment and focus more on areas such as high-mix/low-volume operations, thus moving from prescriptive application to contingency-led approach (Hines et al., 2004; White & Prybutok, 2001; Papadopoulou & Özbayrak, 2005). Engineer-to-order (ETO) operations represent high-mix/low-volume environment that is considered under-researched regarding lean implementation (Hines et al., 2004). Lean strategies have been proposed in ETO sector. However, characteristics of ETO sector might differ significantly from the ones typically found with low-mix/high-volume manufacturers, and extent to which lean practices are suitable for ETO operations has been questioned (Cooney, 2002). Empirical evidence in support of or against lean implementation in ETO operations are fairly limited, any contemporary research suggests that more empirical evidence is needed in order to test the applicability of lean principles in ETO environment (Gosling & Naim, 2009; Naim & Gosling, 2011).

This paper presents the results of empirical research, where lean has been implemented in a company that represent typical ETO manufacturer, supporting the stance that efficiency of ETO operations can be improved through lean implementation. The reminder of the paper is organized as follows: literature review regarding lean, peculiarities of ETO operations, and lean implementation in ETO operations is presented in Section 2; research design is presented in Section 3; the results of empirical research are presented in Section 4; discussion and conclusion follows in Section 5.

2. THEORETICAL BACKGROUND

2.1. Lean manufacturing

Lean manufacturing originated in Toyota after Second World War as a result of scarcity of resources and intense domestic competition on automobile market (Hines et al., 2004; Hopp & Spearman, 2008). Toyota developed a system (Toyota Production System – TPS) that was able to produce greater variety of products with lesser inventory, human effort, investments, and defects (Womack et al., 1990). TPS was developed as an alternative to Ford production system, and often has been seen as a counter-intuitive approach that differs significantly from then dominant mass production (Womack et al., 1990). It was developed and applied under the leadership of Taiichi Ohno (1988), and additionally documented by the likes of Monden (1983) and Shingo (1989).

Monden (1983) is largely responsible for bringing TPS to western audience. His book described in details Just-In-Time (JIT) manufacturing as one of the pillars of TPS (the other one being autonomation, or *jidoka*). Term ‘lean manufacturing’ was coined during the International Motor Vehicle Program (IMVP) research, which was aimed at bridging the performance gap between Western and Japanese car manufacturers. Waste elimination was recognized as a central role of lean manufacturing (Bhamu & Sangwan, 2014), where waste is any system input (transformed resources, transforming resources) that is not transformed into a system output (fulfilled customer demand, this is neither unfulfilled nor exceeded) just-in-time. Womack & Jones (1996) described lean as an antidote for waste, and devised 5 lean principles aimed at eliminating waste: value, value stream, flow, pull, and perfection. Lean was deemed to be universally applicable to wide array of business environments (Womack & Jones, 1996). However, many authors criticize lean for its lack of applicability in operations that differ significantly from low-mix/high-volume environment that lean was developed in (Cusumano, 1994; Hines et al., 2004). Tool based implementation, car-manufacturing focus, and inability to handle variations in demand were recognizes as lean’s main weaknesses (Hines et al., 2004).

2.2. Lean implementation in ETO operations

ETO operations are considered as operations where decoupling point (stock holding point that separates the part of the supply chain that responds directly to the customer from the part of the supply chain that uses forecast planning; see e.g. Portioli-Staudacher & Tantardini, 2012) is located early in the supply chain, typically at the design stage (Gosling & Naim, 2009). It refers to the type of operations where customer actively collaborates in product design, in order to develop and manufacture a product that meets functional requirements of the customer (Birkie & Trucco, 2016). The output of ETO operations is highly customized product that may be a result of modified past design or an entirely new design for every customer (Portioli-Staudacher & Tantardini, 2012). The demand is usually unstable and unpredictable. ETO operations might be associated with large, complex project environments such as construction and capital goods that require extremely high work content and low volumes (Gosling & Naim, 2009; Potrioli-Staudacher & Tantardini, 2012). However, large proportion of ETO operations is conducted by small machine shops, where customer requires design and production of highly customized products in relatively low volumes. These types of operations are often labeled as non-repetitive operations (see e.g. White & Prybutock, 2001). ETO operations are characterized by a high level of dynamism and complexity that create environment that is heterogeneous and unpredictable (Birkie & Trucco, 2016). Traditionally, short concept-to-delivery time and high delivery reliability are deemed to be key priorities for ETO companies, rendering them order winning characteristics in addition to quality (Amaro et al., 1999; Portioli-Staudacher & Tantardini, 2012). Price is considered to be of secondary importance, and is usually seen as order qualifying characteristic (Amaro et al., 1999; Birkie & Trucco, 2016).

Lean is often used to address problems with long lead times and unreliable delivery in repetitive manufacturing environment with stable and predictable demand. This is why there’s a rising interest in lean implementation in ETO companies. Although lean has been suggested as a mean for efficiency improvement in non-repetitive manufacturing, evidence about lean implementation in ETO operations is scarce. Many authors state that lean implementation requires stable and predictable demand, which is unlikely situation in ETO operations (Hendry & Kingsman, 1989; Hüttmeir et al., 2009). Some of recognizable lean tools (such as work cells, takt time, supermarket pool, etc.) are deemed to be inapplicable or even undesirable in ETO environment (Hendry & Kingsman, 1989; Cooney, 2002; Hopp & Spearman, 2008).For example, straightforward and effective tool such as value stream map might be difficult to implement since product flows are often interlaced, resources are being shared, and cycle times differ between different products. Quality at the source might be hard to obtain, since products are highly customized, making it hard to learn from past mistakes. Demand variability, both in volume and mix, makes it hard to level the production in way it is done in environment with stable demand (Lander & Liker, 2007; Stump & Badurdeen, 2009). This might lead to ETO managers questioning the importance that lean might have for non-repetitive manufacturers (Jina et al., 1997). Difficulties in lean implementation might have several causes: (i) knowledge of lean implementation in ETO operations is not as structured and systematized as in repetitive manufacturing; (ii) managers fail to recognize contextual factors of ETO operations, and try to copy lean practice from repetitive manufacturing; (iii) managers fail in understanding underlying principles of lean, and focus on tools; and (iv) there is no unique framework that will guide lean implementation in ETO environment. Many researchers state that evidence on lean applicability in ETO environment is yet to be found, suggesting that more empirical research is needed to support the effects that lean might have on efficiency of ETO operations (Gosling & Naim, 2009; Birkie & Trucco, 2016).

3. RESEARCH DESIGN

The main research question in this paper is:

Can lean improve efficiency of ETO operations?

This section presents the research design established in order to answer the research question. Research design is presented in two subsections. First subsection gives a description of a case company, and discusses the rationale of using single case study approach. Second subsection discusses research approach and step taken in order to obtain the answer to the research question.

3.1. Case company: rationale and description

The research focuses on a single company. Using single company can be appropriate if it provides an opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation, and if longitudinal approach is taken, i.e. if functioning of case company is analyzed over a considerable period of time (Yin, 2013).

Company ALPHA (real name is obscured) is selected as a representative of ETO operations. The company produces Point-Of-Sale (POS) and Point-Of-Purchase (POP) products such as shelves, displays, overhand dispensers, kiosk displays etc. Most products are produced on an ETO basis, where company performs all steps of product realization, from design and engineering, prototyping, to manufacturing and delivery. The company serves a turbulent marking, and has to deal with demand variability both in production volume and mix. Demand is irregular and unpredictable, while products are mostly one of a kind in regard to design and characteristics. The company is subject to all kinds of external influences. Most of them are coming from customers, who are trying to enforce their orders as the most important ones. Product routings vary in sequence and length, although the flow of material is considered to be directed. Production volumes are relatively small, as are orders from suppliers, which makes company subject to supplier influence as well. During the initial interviews with managers and employees, it was concluded that company is not as efficient as it could be. Although there was a 'feel' that operations are not as efficient as they could be, the exact data were not collected or analyzed. For example, lead times were considered long, but precise data on average lead times were not readily available. In addition, the company had difficulties to adhere to promised due dates, but the data on percentage of lateness and average lateness was not available either.

3.2. Research approach and steps

To analyze the possibilities of efficiency improvement in ETO operations, a longitudinal case study was carried out. A considerable period of measurements was undertaken both before (baseline measurement) and during lean implementation (post-change measurement). The research involved cooperation between researchers, company managers and employees. Having that in mind, as well as the fact that research question 'relates to describing an unfolding series of actions over time in a given group, community or organization', the research can be further typified as action research, as a variant of case research (Coughlan and Coghlan, 2002). A process consultation model was chosen. Here, researchers help the clients inquire into their own issues, and actively participate in the design and implementation of the solution (Schein, 1999). A consistent approach was developed and well documented, so it can be followed by other researchers (Westbrook, 1995). Researchers' subjectivity was mitigated by including management and employee representatives in the research team. All decisions were made by consensus. In turn, employee subjectivity was mitigated by the presence of researchers. Research was conducted in three phases (Figure 1). First, base efficiency measurements were taken in order to enable researchers to understand the current situation, and to establish a baseline to which results obtained in later stages could be compared. Two types of measures were taken: (i) average lead time; and (ii) delivery reliability, measured through percentage of late orders and average lateness. Then, lean was introduced to the company. Afterwards, second set of efficiency measurements followed. Additional data were gathered from archival sources and semi-structured interviews with managers and employees.

Figure 1: Research phases

Baseline efficiency measurement

Baseline efficiency measurement was done based on an existing data collection system. During interviews with company management, lead time and delivery reliability were identified as order winners. This is why it was decided that lean implementation efforts should be aimed at shortening lead times and improving delivery reliability. Lead time was measured as the difference between the time when order left the company and the time when order entered the company. Delivery reliability was measured through percentage of late orders (number of orders delivered late divided by total number of orders), and average lateness (the difference between actual and promised delivery dates). Data was collected continuously, for each order. Collected data was later analyzed together with managers and employees of the company.

Lean implementation

A tool-agnostic approach to lean implementation was taken, meaning that focus was on underlying lean principles rather than on lean tools. Specific problems were analyzed in the light of lean principles, while tools were developed and used in accordance to identified problems. Lean implementation was guided by lean definition given by Hopp & Spearman (2004), where production of goods is considered lean if it is accomplished with minimal buffering costs. There are two sources of excess buffering. First source is obvious or big waste that has no rational reason for existence (Liker & Meier, 2006). This includes operations that are not needed, unreliable machines, rework, unnecessary waiting, excessive setup times, etc. This type of waste can be reduced without creating another form of waste is obvious waste. Second source of excessive buffering is variability that can take on many forms, including variability in process times, delivery times, yield rates, staffing levels, demand rates, etc. Variability can be external (irregular demand, product variety, changes in orders, etc.) or internal (excessive processing steps, unnecessary movements, setups, etc.). If variability exists it will be buffered with one of the following types of buffers: inventory, capacity or time. This is the type of waste that cannot be reduced without creating another waste (according to Little's law, changing one buffer without addressing the source of variability affects the size of other buffers, see e.g. Little, 1961).

Based on the lean definition presented in the text above, conceptual lean implementation model was designed and followed (Figure 2).

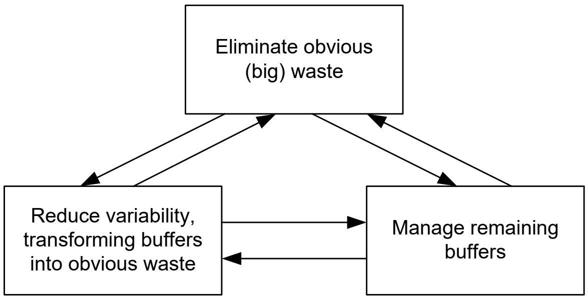

Figure 2: Lean implementation conceptual model

Eliminating obvious waste means removing everything that does not add value to the customer, and has no rational reason for existing. Reducing variability (both internal and external) decreases the requirements for buffers, thus transforming buffers to obvious waste (i.e. less variability removes reasons for buffers to exist). Variability that remains must be buffered or isolated in order to reduce the impact of variability on the entire value chain. The remaining buffers must be right-sized and balanced (i.e. by exchanging expensive buffer such as inventory for a less expensive one such as capacity) in order to improve flow and reduce the cost of buffering.

Over-processing and waiting were recognized as most significant obvious waste. Over-processing starts at engineering, where engineers thought that products that are more complicated then customer required had more value. In addition, engineers were pressured by short due dates, which prevented product refinement. This means that product manufacturability was rarely analyzed, which led to over-processing in manufacturing. Other obvious waste is waiting, where about two thirds of the entire lead time the order spends waiting. Uncontrolled order release was identified as main cause of waiting, since it leads to high levels of WIP and shop-floor congestion. This problem was resolved through controlled order release, based on input output control. Input control (releasing new orders based on the shop load) was deemed to be less feasible, because delaying order release was usually not possible, since due dates are usually tight. Shop-floor congestion was mainly resolved through output control, i.e. short-term capacity adjustments (overtime or additional shifts) with the aim of increasing throughput. In addition to eliminating over-processing and waiting, operations were analyzed in order to identify and eliminate unnecessary activities and motion.

Variability was reduced mainly through standardization. Operations were analyzed and improved, and new standard operating procedures (SOP) were introduced. SOPs consist of three parts: (i) first part contains information about workplace preparation; (ii) second part contains information about performing operations on a workplace; and (iii) third part contains information regarding preventive maintenance of production resources and workplace. Greatest challenge was to create SOPs for assembly, since sequence and content of assembly operations might differ significantly from one order to another. This was resolved through division of assembly operations to smaller elements (different ways of putting elements together) which were standardized and written down to a SOP. SOP for an entire product is obtained by combining different SOPs for elements of operations. Special attention was given to setup reduction, where SMED (Single-digit Minute Exchange of Die) method was applied. Setup activities were analyzed and standardized, and new setup procedures were devised. Prototype production was a major source of variation. Engineers used to make requests for prototype production in an unstructured and erratic manner, thus interrupting production and introducing additional variability. This was resolved by introducing time slots (one hour at the beginning of each shift) which were used entirely for prototype production, while producing prototypes outside of this time slots was possible only by order of production manager.

Remaining variations were isolated through buffer introduction. First buffer was introduced at order acceptance phase in order to separate operations from demand variations. Orders were placed in an order pool, from which they were picked and released according to available capacities of engineering department. Engineering process is unstructured and unpredictable, and presents significant source of variation. In order to prevent transfer of variations to manufacturing, another buffer (pool) was introduced after engineering, and before manufacturing, so impact of variation could be isolated in engineering department. High WIP levels were used to buffer internal variability. They were used as a source of autonomy, where it was up to operators to select next order to be processed. The result was los of 'natural' flow of orders, shop-floor congestion, difficulties in tracking orders, orders getting lost, etc. this was resolved through 'swapping' one buffer for another, i.e. inventory (WIP) buffer for capacity buffer. As it was said earlier, controlled order release could not be obtained through input control, so it was obtained through output control, i.e. increase of throughput. Capacity slack was created through short-term capacity adjustments that were used when shop-floor was threatened to be congested. Work center load was used as a capacity adjustment trigger. Maximum allowed work center load was determined, and capacity was adjusted when it was estimated that maximum allowed load was to be violated. Lowering levels of WIP allowed for material to be moved through shop-floor in accordance to FIFO principle, thus lowering demand for order dispatching.

All actions aimed at waste elimination, variability reduction, and buffer management should be taken in accordance to scientific approach, i.e. through usage of PDCA cycle.

Post implementation efficiency measurement

Post implementation measures were taken during and after lean implementation. In order to facilitate gathering of data, new order tracking system was designed. New system facilitated information gathering and analysis, since data was collected in a way that enabled their use without significant amount of data processing (i.e. it was possible to analyze data in their 'raw' form). As was the case in baseline period, data was collected continuously, for each order. Data was gathered and analyzed together with managers and employees.

4. RESULTS

Data on lead times and delivery reliability were taken during 2015. The entire period was divided in two shorter periods, in order to track changes in lead times and delivery reliability before and after lean implementation: (i) period 1 – weeks 1 to 35, before lean implementation; and (ii) period 2 – weeks 36 to 52, after lean implementation. Figure 3 shows average lead time before and after lean implementation. Although measurements were taken per work order, the results are grouped per week, for the sake of better visibility.

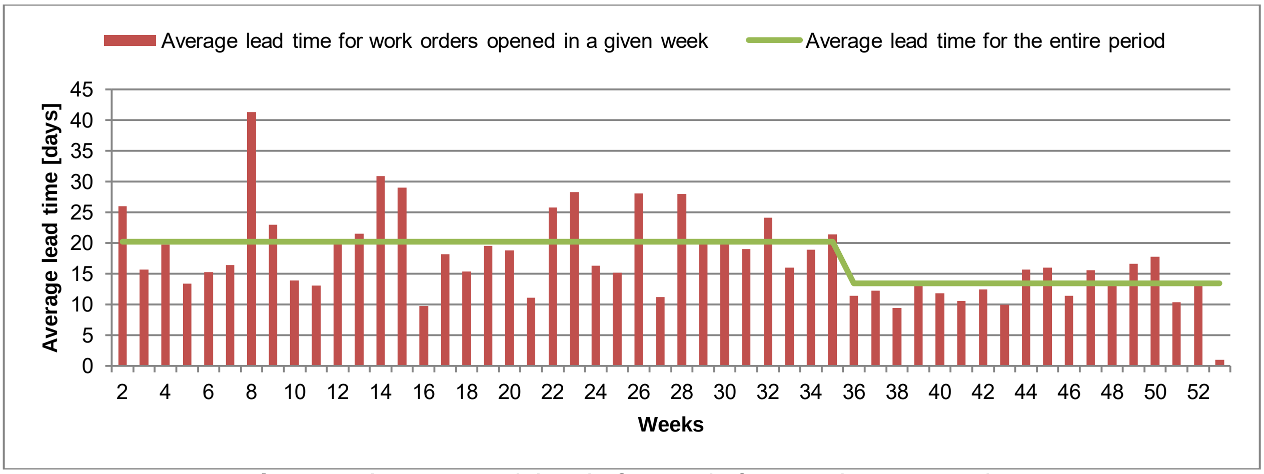

Figure 3: Average lead time before and after lean implementation

The results show that average lead time after lean implementation is shorter than the one before implementation. Before implementation, average lead time was 20.17 days, while after lean implementation it was reduced to 13.43 days. Standard deviation of lead times was also reduced, from 19.8 to 10. Decrease in lead times was obtained through two main courses of actions. First course of action was reducing and controlling variability, both in effective processing times and inter-arrival times. Reduction in processing times and inter-arrival times resulted in reduced wait time, which was estimated to 13 days before lean implementation (net time was estimated to be around 7 days). Processing time variability was reduced through waste elimination, standardized operating procedures, setup time reduction and standardization, and improved maintenance. Inter-arrival time variability was reduced through separation of demand and production, with introduction of two order pools in front of and right after engineering department, aimed at stabilizing the inflow of new orders, both in the company as a whole, and in manufacturing. These results support the claims presented by Kingman (1961) that waiting time in queue is directly influenced by variability. Second course of action was in accordance to Little's (1961) law, where lead time is affected by throughput rate and WIP. With tight due dates and constant pressure, it was hard to limit the amount of WIP on the shop floor, co congestion was managed through output control, i.e. short term capacity adjustments such as overtime and additional shifts.

Figure 4 shows the distribution of lead times before lean implementation and after lean implementation.

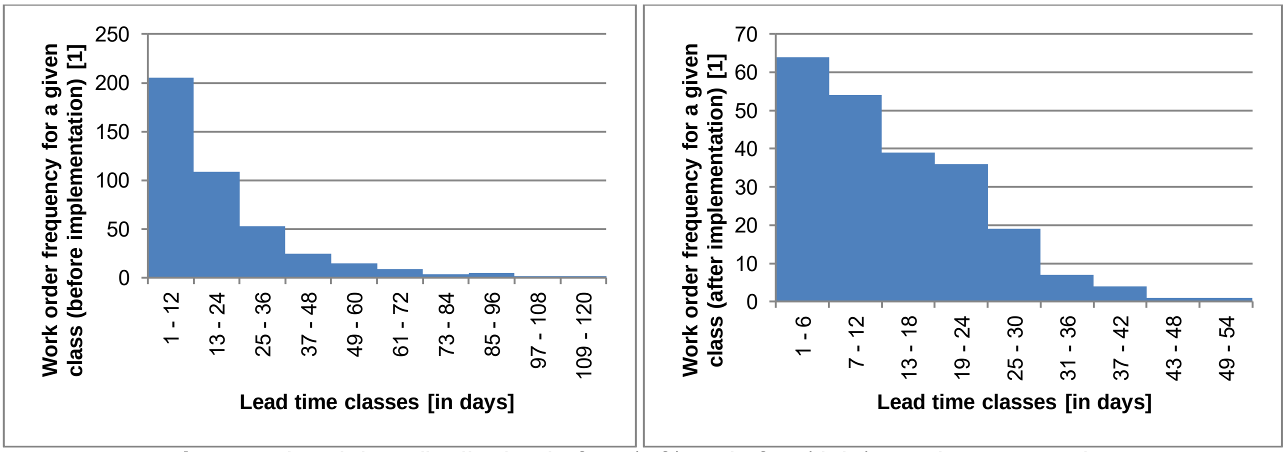

Figure 4: Lead time distribution before (left) and after (right) lean implementation

The results show that lead time range is significantly smaller after lean implementation, which effected the average lead time itself. In addition, more control of work orders was established through lean implementation, which is supported by the fact that lean implementation eliminated work orders with extremely long lead times. This led to less congestion on the shop floor, which reduced the opportunities to change order priorities, as well as the need for order dispatching. As a result, it became possible to use simple dispatching rules, such as FIFO, and to maintain the 'natural' flow of orders.

Figure 5 shows number of work orders completed before due date, on time, and after due date. As before, weeks 1 to 35 are before lean implementation, while weeks 36 to 52 are after lean implementation.

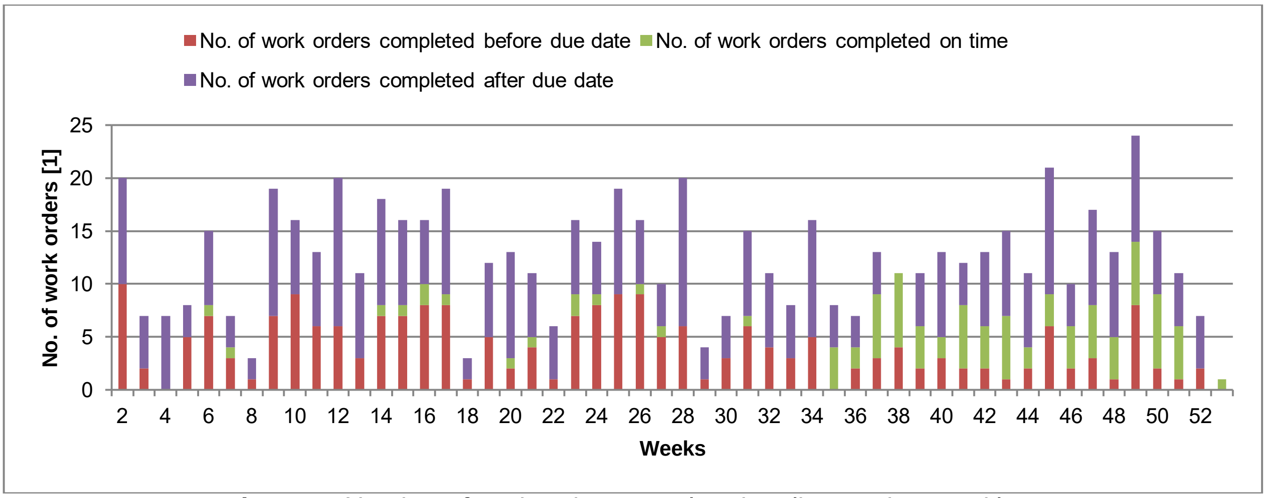

Figure 5: Number of work orders completed earlier, on time, and late

The results show that number of work orders completed late was lower after lean implementation. The percentage of late orders decreased from 55.5% to 46.7%. In addition, the number of work orders completed on time increased significantly, as shown on Figure 5. As a result, less work orders were completed late, as well as early, which increased service level of the company.

The distribution of lateness was also analyzed, as shown in Figure 6. The results show that, while lateness range stayed rather unchanged, distribution function became much narrower after lean implementation (right hand side if the figure). The results show that work orders are accumulated in a class that represents work order completion on time, or with a minimal earliness or lateness.

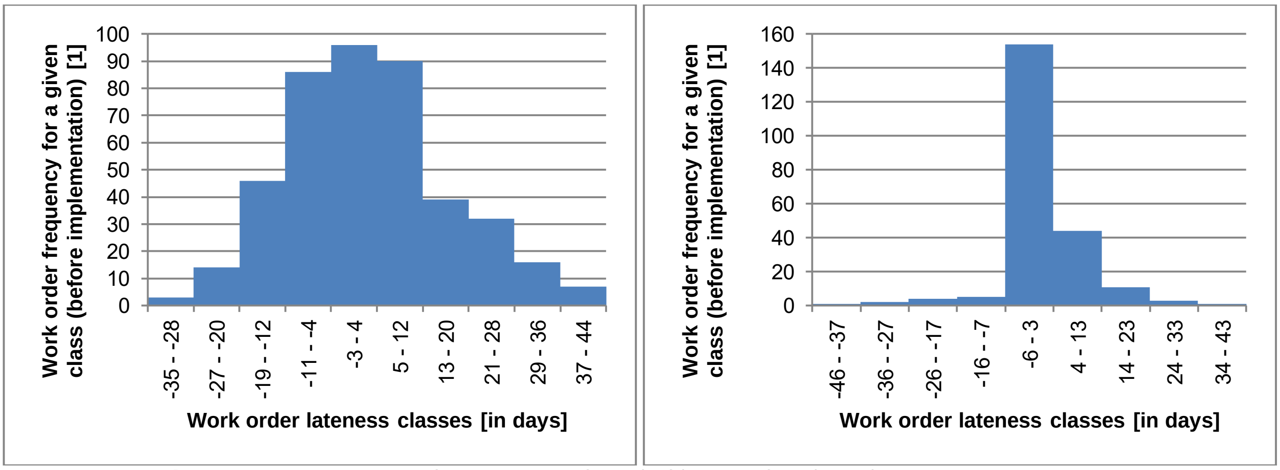

Figure 6: Distribution of lateness before (left) and after (right) lean implementation

Results presented in Figures 5 and 6 suggest that average lateness should have decreased after lean implantation. In order to test this hypothesis, average lateness before and after lean implementation was measured in details. The results are presented in Table 1.

Table 1: Average lateness before and after lean implementation

	Period	Sample size	Average	Standard deviation
Average lateness	Before	238	12.7269	9.83948
	After	105	7.1619	7.11056

The results show that average lateness decreased from 12.7 days to 7.2 days. In addition, standard deviation of lateness decreased from 9.8 to 7.1. Lead time reduction had a great impact on delivery reliability improvement, supporting the claim that improved delivery reliability can be a consequence of shorter lead times and/or lower standard deviation of lead times.

5. CONCLUSION

Evidence of lean being used from efficiency improvement in repetitive manufacturing are abundant. However, evidence of lean being used to improve efficiency of ETO operations are few and far between, thus raising the question of lean universality. This paper presents the results of an action research in efficiency improvement in an environment that is often considered as inappropriate for lean implementation. The results obtained through the research add to the fact that lean can be used for improving efficiency of ETO operations. ETO companies operate in turbulent environment, which is a fact they often use as an excuse for efficiencies. Variability is inherent to ETO operations, since ETO companies ‘sell’ variability, both in production mix and volume. So, rather than passively reacting to variability, ETO companies should take a more proactive stance, and put efforts to actively control variability. The fact that ETO companies ‘sell’ variability calls for caution. Some variability should be reduced, while some should be isolated and controlled. If there is no rational reason for variability to exist, then it is waste and it should be eliminated. If variability has to exist, it has to be managed as much as possible, and buffered in an effective way.

Production system introduced to company ALPHA was not a copy of TPS. This means that lean implementation was not formulaic, stripped down to mere tool implementation. Rather, it was TPS based production system, built on underlying lean principles that were used by Toyota to develop tools for specific problems. This approach reduces chance for failure, since it is advocates contextual approach that avoids prejudging solutions, but takes into account characteristics of a specific manufacturing environment and builds efficiency improvement on laws that define lean.

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RESHAPING THE FUTURE THROUGH SUSTAINABLE BUSINESS DEVELOPMENT AND ENTREPRENEURSHIP

TOWARDS SUSTAINABILITY: MASS CUSTOMIZED-LEAN-AGILE-FIT OPERATIONS MANAGEMENT IN BANKING

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Abstract: *This paper aims to deepen and broaden the scientific fund of recently advocated paradigms that will significantly reshape operations management in banking industry in years to come. The purpose of this paper is to guide operations managers in banking towards economic sustainability by providing a conceptual architecture of digital platform for operations services to reduce complexity, time to market, and at the same time to visualize operations activities, i.e. to effectively support mass customized-lean-agile-fit operations strategies. Further, taking into account that the major challenge in mass customization paradigm is to determine product offerings, the paper provides a two-phase approach consisting of Total Unduplicated Reach and Frequency (TURF) analysis to facilitate a choice of new services imposed by market requirements and Analytic Network Process based on BOCR model (ANP-BOCR) to segregate a core from actual and augmented mass customized services. The study may be useful for operations managers in financial services, innovation, IT and business decision management.*

Keywords: *Operations management, mass customization-lean-agile-fit operations strategy, banking industry, economic sustainability, conceptual architecture of digital platform, TURF analysis, ANP-BOCR method.*

1. INTRODUCTION

The concept of sustainable development has been extensively studied from various aspects in the theoretical literature over the time. The analysis of hundreds definitions of sustainable development concept depicts that there is no unique and comprehensive formulation which provides clear understanding of the phenomenon due to its complex and multi-dimensional issue, which indicates that sustainable development should be considered as an integrated system of economic, ecological, social and institutional perspectives (Jiliberto, 2003; Ciegis et al., 2009).

In the face of an intense competition, comprehensive changes in technology, customers' demands, regulatory requirements and demographic changes into the volatile business environment, strategic managers worldwide understand sustainable business development not only as an option, but as a fully integrated paradigm into the strategy and operations of organizations. According to the Lacy et al. (2010), ninety-three percent (93%) of the 766 CEOs have stated that sustainability is significant issue to the organization's future success. Yet, businesses worldwide are rapidly digitizing, breaking down industry boundaries, building new opportunities, and at the same time harming long-successful business models (Weill & Woerner, 2015; Tornjanski et al., 2015). The phenomenon of digital disruption remarkably changes banking industry, indicating the considerable redesign of operating model in years to come. These underlying influences put sustainability in narrow focus of executives and at the same time create big pressure on banks to continuously evolve, by changing its strategic context and competitive dynamics (Propa et al., 2015; Weill & Woerner, 2015). In such circumstances, operations management as a central core function and its dynamic capabilities are of strategic importance to an organization (Brown et al., 2013), taking into account its significant role in overall organizational performances (Slack et al., 2004; Zangiski & da Costa, 2013). In the age of the third industrial revolution, adjusting complexity, harmonizing confronted requirements and dynamic processes with all accelerated changes under uncertainty, while effectively managing both internal and external interdependencies with various stakeholders that have different requirements and needs, have always represent challenge for operations management in banking. However, in the volatile times, it became challenge of key importance for organizational sustainability and business development (Slack, 2015; Sprogies & Schmidt, 2015).

Given that banking sector is undergoing significant transformation towards structure that follows principles of flexibility, openness and customer-centricity, sustainability from operations management aspect may be achieved if operations managers in banking industry understand what they have to provide and how to leverage resources and capabilities as an integrated system (Fasnacht, 2009; Huo & Hong, 2013; Tornjanski et al., 2015a).To this end, operations managers in banking industry have to develop the ability to tailor the appropriate strategies with clear long-term vision and strong short-term implementation capacities to effectively boost transformation of operating model from traditional "back-office" role toward "strategic" role with the possibility not only to support business strategies, but also to shape new ones for well-being of an organization on the long run (Henderson & Venkatraman, 1999).

With that in mind, this paper aims to extend and deepen the scientific fund of recently advocated paradigms that will significantly reshape operations management in banking industry in years to come. The purpose of this paper is to guide managers in banking to effectively support mass customized-lean-agile-fit operations strategies. Further, taking into account that the major challenge in mass customization paradigm is to determine product offerings, we aim to provide a framework to facilitate strategic decision making.

2. LITERATURE REVIEW

The field of operations management in service organizations has evolved tremendously over the years due to changes in market requirements (Gunasekaran & Ngai, 2012). The dynamic customer expectations, increased competition, advancements in information and communication technologies, development of knowledge-based economy (Kriščiūnas & Daugėlienė, 2015), financial market globalization and economic recession have forced service operations managers to approach the transition (Vinodh et al., 2014). The fundamental requirement in transition is change of operating models which implies an introduction and application of appropriate strategies and paradigms towards continuous operations improvements. As a result, service operations management has entered into the “mass customization-lean-agile-fit” era (Zhao & Lee, 2009; Gunasekaran & Ngai, 2012; Brownet al., 2013; Tseng & Hu, 2014; Vinodh et al., 2014), which significantly reshapes operations management in service sector today.

2.1. Mass customization

Mass customization has emerged as an important paradigm due to the heterogeneity of individual needs, competitive intensity and shortens product life cycles (Huang et al., 2008; Khalili-Araghi & Kolarevic, 2016).There is a wide variety of understandings of this phenomenon viewed from different perspectives. From a customer perspective, the paradigm enables superior customer value by providing products / services that meet individual needs (Tseng& Jiao, 2001). From the service operations management perspective, mass customization refers to the ability to quickly provide customized products in high volumes, with quality that will satisfy end user, minimal costs and time to market (MacCarthy et al., 2003). In other words, mass customization is a “paradigm that seeks, as its goal, to combine the value-added effectiveness associated with product customization with the cost-efficiency closely related to mass production” (Huang et al., 2008, p. 716). According to the Papathanassiou (2004), development of customized services is recognized as one of the top priorities in the service industry nowadays. However, customer driven business is both, an imperative and a potential threat. Gilmore & Pine (1997) pointed out that many companies have introduced new procedures and programs to meet every customer's requirement. Yet, such approach has caused additional costs and complexity to operations. In response to this issue, four unambiguous approaches to customization have been advocated, i.e. collaborative, adaptive, cosmetic and transparent customization. Pine et al. (1995) suggest that modular system, information availability to employees, incorporation of customers into an evaluation process for product / service development and creation of direct link with customers are elements that should be taken into account when companies embark development of mass customization strategies and architectures.

This concept shifts design, distribution and processes from "made-to-stock" to "made-to-order", which significantly challenges the conventional product development, process and supply chain management (Tseng & Hu, 2014).To effectively support mass customization strategy, organizations should reconsider the entire value chain from front to end, by efficiently adjusting economy of scale, variety and time to market (Tseng & Hu, 2014) and effectively managing the dynamics and trade-offs among product design, system design and supply chain design (Hoekstra & Nahmens, 2005).

2.2. Lean, agile and fit framework for service operations management

Lean philosophy advocates elimination of any kind of waste, including a reduction of non-value-added activities to continually improve company’s wealth creation capability (Droste, 2007; Lester, 2008; Womack & Jones, 2010). Although manufacturing organizations were the beginners of lean adoption (Hines et al., 2004), service organizations are increasingly inspired by lean management. Among all, financial services are pressed to improve operational efficiency due to strict governmental regulations and intense competition determined by non-financial companies and changes in customers' behavior (Staikouras & Koutsomanoli-Fillipaki, 2006; Leyer & Moormann, 2014). Despite increased interest in the application of this paradigm, financial services often experience difficulties in successful adoption of lean. One of the reasons lies in an insufficiently explored phenomenon in financial services in both, the theory and practice. Leyer & Moormann (2014) have stated that only few case studies dealt with the applicability of lean in financial services. Prior theorists note that implementation of manufacturing lean principles in financial service organizations cannot be treated equally due to their contextual differences (De Treville & Antonakis, 2006), i.e. differences in nature of goods and services, operation processes and the way of customer integration in manufacturing and financial service organizations (Leyer & Moormann, 2014).

Early works on lean principles specify two fundamental criteria that characterize lean: just in time (JIT) and automation. Just in time represents a "pull" system in which production process starts only when it is signaled by the customer downstream, while the objective of automation is not to throw out production employees, but rather to shift them on those aspects of business which create the highest value (Womack & Jones, 1996; Ohno, 1988; Staats et al., 2011). Value, value stream, flow, pull, and excellence are five categories that refer to definite lean management concept (Womack & Jones, 1996). Value refers to a product / service that is offered to customers, along with the works backward to build an operation process. Value stream ensures that each step creates value in value chain. Flow reorganizes processes in order to have smooth delivery operation through the value-creation exercise, while pull represents a mechanism for limiting waste in operation processes (Hopp & Spearman, 2004). Finally, excellence requires continual striving to meet customer requirements, and at the same time to improve processes with zero defects (Staats et al., 2011). Mefford (1993) stated that just in time, high performance work systems and total quality management are management practices that characterize lean paradigm. However, Shah & Ward (2007) argue that these practices are not sufficient to adequately explain an entire idea of lean management (Leyer & Moormann, 2014). According to De Koning & De Mast (2006), lean represents an integrated system of principles, tools, techniques and practices aimed at waste reduction, synchronization and management of workflows in organization. In addition, Rother (2009) recognizes that employees' capability to think and act towards lean, i.e. to be focused on efficiency and value-creating processes in day-to-day business activities is equally important element in lean management. In accordance to that, a change in an organization's management system is perceived as an important element for sustainable implementation of lean management, too (Mann, 2014; Leyer & Moormann, 2014). A common denominator in all lean aspects is fundamental idea of optimization and continual improvement of operations processes (De Koning et al., 2008). The adoption of lean philosophy in organization is assumed to be in positive correlation with increased efficiency (Dahlgaard & Dahlgaard-Park, 2006), and in negative correlation with cycle time and costs, which results in more agile, customer-responsive and competitive organization (Alukaj, 2003).

Agile service operations management requires quick respond to changes in demand in terms of both volume and diversity (Christopher, 2000; Power et al., 2001). Naylor et al. (1999) defines agility as a usage of market knowledge and a virtual organization to bring about profitable solutions and alternatives in a volatile marketplace. According to the Power et al. (2001, p. 247) "The notion of agility is therefore recognized to be holistic rather than functional, and of strategic rather than tactical importance. The concept has also been extended beyond the traditional boundaries of the individual organization to encompass the operations of the supply chain within which the organization operates". It has been argued that organizations could thrive in rapid and unpredictable business environment by acting in an agile manner (Nagel & Dove, 1991; Bruce et al., 2004).

A holistic approach that integrates mass customization, lean and agility, i.e. fit framework is a new model for economically sustainable organization (Pham & Thomas 2011; Vinodh et al., 2014). Prior theories strengthen fit framework which combines these concepts and allow organizations to tune its operational and technological capabilities (Pham & Thomas 2005). Fit framework provides a new operations management perspective and new operations management strategy to accomplish dynamic strategic objectives. Innovative concept with holistic perspective, built upon the principles of these paradigms, is recognized as an effective strategy towards organizations' economic sustainability (Pham & Thomas 2005; Pham & Thomas 2011; Vinodh et al., 2014) and should be integral part of strategic and sustainable strategies in banking industry, too.

3. METHODOLOGY

For the purpose of this paper, the method of case study has been recognized as the most suitable research method to deeply understand the role and issues of operations management in banking, thus to ensure a holistic view on the researched phenomena in real life. Within the case study, we have incorporated a multi-method approach to strengthen the results on a given research problem.

To understand a specific problem, in-depth interviews were conducted with the senior managers in operations area of the bank under the study as a targeted sample of respondents for the sake of ensuring that the participants meet the requirements to be included in the study.

Thereafter, to answer "how" to effectively support mass customized-lean-agile-fit operations strategies in banking, we have developed a conceptual architecture of digital platform for operations services to reduce complexity, time to market, and at the same time to visualize operations activities. Further, taking into account that the major challenge in mass customization paradigm is to determine product offerings, i.e. in order to understand "what" operations management needs to provide to internal and external stakeholders to meet both strategic goals and end users' requirements, we propose a two-phase approach for selection process.

Phase I

First phase encompasses the selection of new services. The beginning of process is based on the principles of mass customization paradigm, which implies the inclusion of end users in the evaluation process. A survey method is carried out among experts of the bank under the study by conducting a web-based questionnaire as a survey instrument. Experts of the bank were asked to select the combination of proposed services with the aim to ensure that the possible introduction of new services would reach its maximum usage according to the business needs.
In other words, $y_i=\{1, end\ user\ i\ will\ use\ service; 0, end\ user\ i\ will\ not\ use\ service\}$. The results are derived using a Total Unduplicated Reach and Frequency (TURF) analysis that is substantiated by the equations (1) and (2) (Serra, 2013):

Equation 1 is used to reach maximum penetration of final combination of services, i.e. number of end users that are subjected to a limited number of varieties.

$$\max\ Z = \sum_{i=1}^{m} y_i \tag{1}$$

Equation 2 is used to reach maximum frequency of varieties, i.e. the highest number of selected services by each user.

$$\max\ Z = \sum_{i=1}^{m} f_i y_i \tag{2}$$

The results of TURF are analyzed in Excel spreadsheet with the advanced option for solving mathematical programming problems.

Phase II

Second phase implies final selection and segregation of core from actual and augmented mass customized operations services. In this phase, the Analytic Network Process (ANP) multi-criteria method is applied in modelling and quantitative analysis of service lines and their relative weights in regard to benefits, opportunities, costs and risks (BOCR) (Saaty & Vargas, 2001; Saaty & Ozdemir, 2005; Saaty, 2009; Tornjanski et al., 2014) to estimate all the effects when making decision. Final BOCR decision model is shown in Figure 1. Pair-comparisons is carried out by decision maker of the bank under the study using a nine-point Saaty's scale.

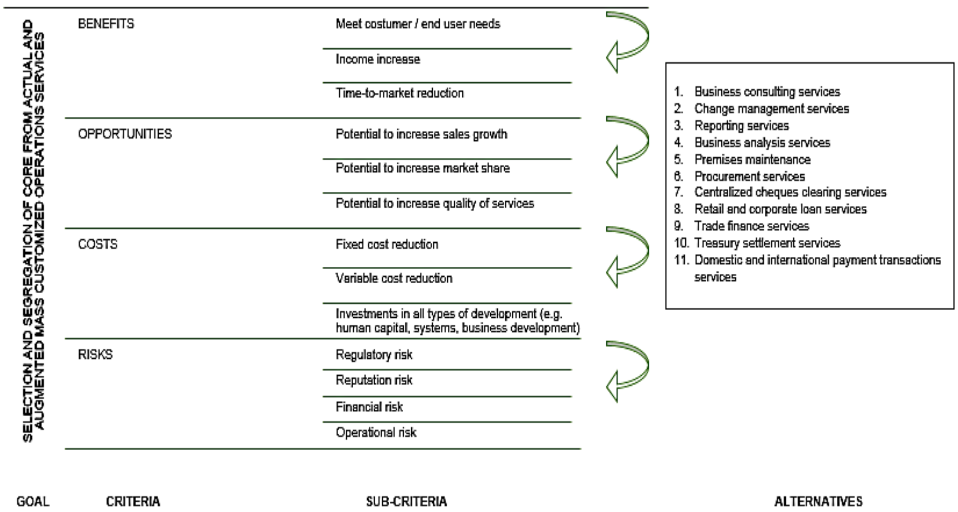

Figure 1: BOCR decision model (Source: Authors)

According to the pair-comparison matrix, local priority vector is obtained by solving (3) (Liang & Li, 2008):

$$A\omega = \lambda \max W \tag{3}$$

Where
A is the pair-comparison matrix
Λmax is its largest eigenvalue
W is the local priority vector.

Next, unweighted supermatrix, weighted supermatrix, cluster matrix and limit supermatrix are constructed. In order to obtain final results, the whole model is synthesized. To calculate the final rank of alternatives, Saaty proposes two ways of calculation. In this paper, the subtractive method is applied using the formula (4) (Saaty & Ozdemir, 2005; Saaty, 2008; Liang & Li, 2008; Tornjanski et al., 2014):

$$bB + oO - cC - Rr \tag{4}$$

Where
b, o, c, r are the priorities for BOCR merits in regard to strategic criteria (Liang & Li, 2008). The results are derived using Super Decisions software package for decision making.

4. RESULTS AND DISCUSSION

The bank under this study (hereafter: the bank) is a European bank which began operations in Serbia in 2003. Today it services more than 900.000 clients with 1.500 employees. With total market share of 4.61% it is ranked among the top 10 banks according to balance sheet assets in the banking sector of Serbia (NBS, 2015).

4.1. Understanding the problem

In an in-depth interview conducted in the bank, decision maker stated: "*Operations function in our bank represents an engine of the organization which simultaneously provides services, information and knowledge to numerous internal and external stakeholders that have different and often confronted requirements* (Figure 2)*. Nevertheless, during the years of successful business in Serbia, Operations function has significantly contributed to the results of the bank, mainly due to established strategic alignment with business strategies and proper management of operations. These and many other efforts invested by the management and experts' team from the Operations function have resulted in an overall improvements of the bank's performances…*"

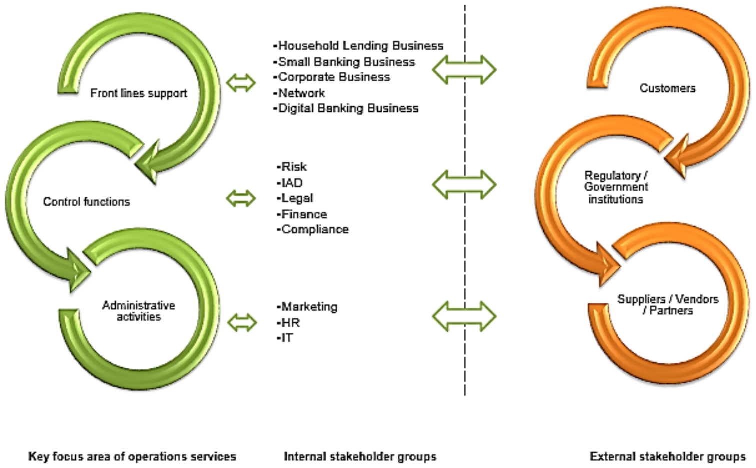

Figure 2: General overview of key focus area of operations services and stakeholders (Source: Authors)

However, decision maker emphasized that: "*Operations function should continue to evolve to ensure economic sustainability for the bank. To this end, we have recognized that it is of paramount significance to develop a model which will visualize operations activities, reduce complexity and time to market with the possibility to effectively support mass customized services and lean operations strategies into everyday business*".

Further, one of the senior managers of the bank has explained the role of operations management and pointed out issues that disrupt operations management today: "*Operations management faces multidimensional complexity when looking for ways in supporting all functions of the bank in achieving sustainability. Regardless of the organizational model followed by the bank, operations activities are placed at the core of the bank right in the crossroads of support to frontlines facing customers, managing administrative functions facing third party vendors and facilitating control functions facing regulatory bodies. Such position puts great challenge on operations managers to determine the right product and resources mix given that it needs to respond both to continuous changes in demand on all internal functions it supports and all external parties those functions are exposed to, in parallel ensuring that costs and resources are kept at optimum level and easily adjustable to changes. This clearly gives additional significance to question of achieving sustainability when operations managers are concerned. To this direction the first aspect which needs to be put in place is segregation between core and additional services which one operations manager needs to support. It is clearly dependent as priority by regulatory requirements as for such activities there is no alternative, but going further from those the variety of indicators coming from market needs (e.g. digitalization), top management strategic focuses (e.g. corporate vs. retail banking), external opportunities for collaboration (e.g. outsourcing) needs to be continuously evaluated in order to provide balanced operational support. Common denominator which always needs to be considered is available resources and how to keep them as flexible as the demand. This is where appropriate models will play the key role for operations managers. All operations managers inevitably will have available or even participate to design of variety of information influencing their activities such as market information, sales targets, product development plans, procurement plans, regulatory requirements, budget forecasts. Key challenge is how to filter all those data in order to identify key indicators which ought to shape operations manager strategy and how to monitor and have early alert on changes of those indicators in a way to efficiently adjust and prioritize operations services and resources".*

4.2. Towards mass customized-lean-agile-fit operations management

Conceptual architecture of digital platform for operations services aims to reduce complexity, time to market, and at the same time to visualize operations activities, i.e. to effectively support mass customized-lean-agile-fit operations strategies. Conceptual architecture of digital platform for operations services is shown in Figure 3 and aims to link value chain from front to end in order to provide mass customized services, information and knowledge, to enable continuous optimization, improvement of operations processes by eliminating waste and by allowing quick respond to changes in demand in terms of both, volume and diversity.

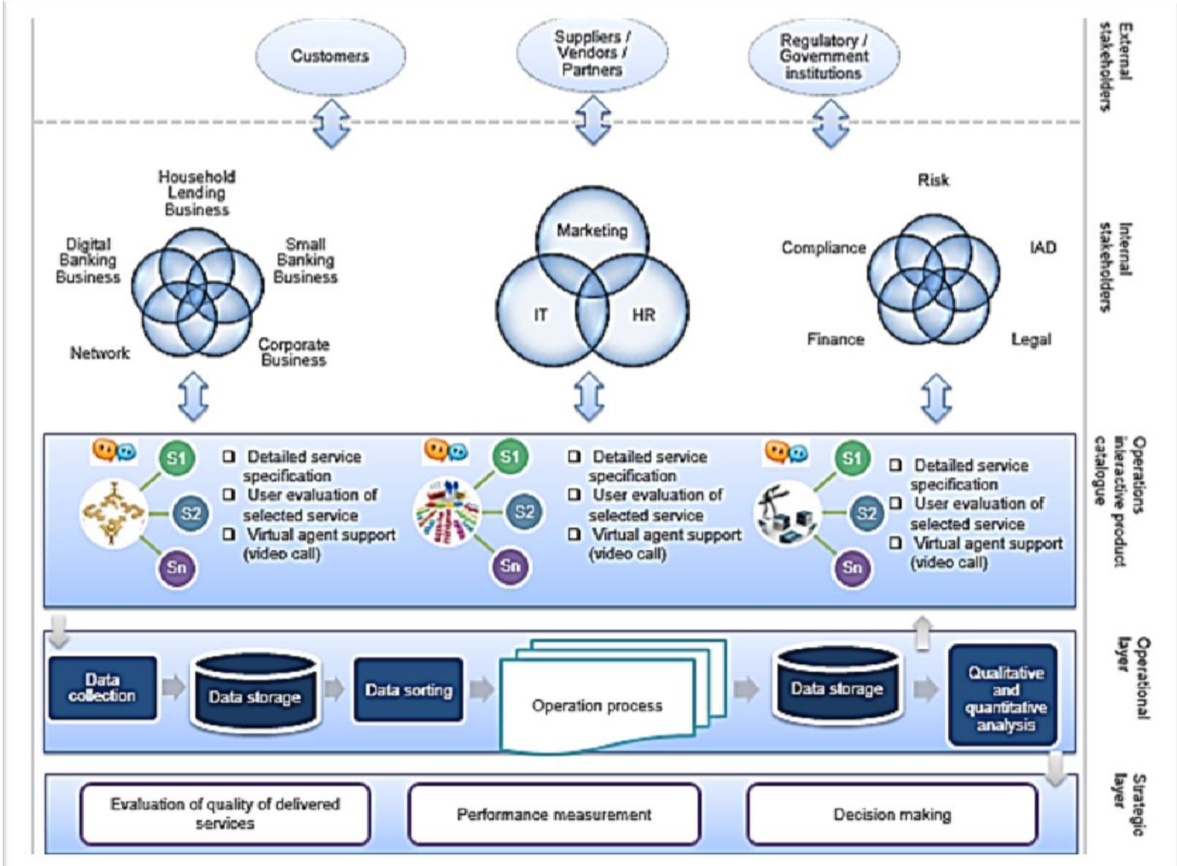

Figure 3: Conceptual architecture of digital platform for operations services (Source: Authors)

The platform consists of three layers. First layer of the architecture represents operations interactive product catalogue which allows users self-service by selecting multiple available services, in any combination, provided by operations function. Each service has a detailed specification to enable stakeholders sheer understanding of the offer in real time, and at the same time enables interactions with experts from the organizational part which delivers service by using on-line chat for instant support, and video call for deeper understanding of addressed issue. Besides, users at this level have possibility to evaluate quality of delivered services by particular organizational part of operations function.

Second layer of the architecture represents operational layer with the purpose of collecting, storing and sorting data of requested services, thus allows adequate allocation of selected service to particular organizational part that should deliver service. Furthermore, it enables storage data after delivered service for further control and analysis.

Third layer of the architecture represents strategic layer which aims to yield an insight into the quality level of delivered services, results of organizational performances, as well as to ensure effective support in decision making using qualitative and quantitative data.

4.3. Selection of new and segregation of core from actual and augmented mass customized services

4.3.1. TURF analysis results for selection of new service line

According to the market requirements, five new services are recognized as significant contributors to the sustainability and thus proposed by the authors of the paper to be further evaluated for operations division catalogue. The evaluation process was performed by 39 experts of the bank, who have selected a combination of proposed services based on the business needs. The results are presented in the following tables. Table 1 encompasses the frequencies at which the objective is achieved for each single service.

Table 1: Frequency table for each single proposed service

Proposed services	Frequency	Frequency (%)
Innovation and development management services	5	13
Strategic and operational planning services	2	5
Change management services	14	36
Reporting services	29	74
Business consulting services	30	77

The following table provides the best combinations obtained from experts' assessment, each time with the reach and the frequency obtained. The reach is the number of end users who intend to use at least one service, while the frequency represents the number of times a service received a maximum score. The results are shown in Table 2.

Table 2: The best combinations for introduction of new services

Service line	Reach	Frequency	Service 1	Service 2	Service 3
Line 1	37	73	Change management services	Reporting services	Business consulting services
Line 2	35	64	Innovation and development management services	Reporting services	Business consulting services
Line 3	35	61	Strategic and operational planning services	Reporting services	Business consulting services
Line 4	34	49	Innovation and development management services	Change management services	Business consulting services
Line 5	34	46	Strategic and operational planning services	Change management services	Business consulting services

Finally, Table 3 depicts a two-way TURF results, derived from the selected service lines.

Table 3: Two-way TURF results

	Line1	Line2	Line3	Line4	Line5	% X
Reach	37	35	35	34	34	
Reach (%)	94.87%	89.74%	89.74%	87.18%	87.18%	
Innovation and development management services		14.29		14.71		40.00
Strategic and operational planning services			5.71		5.88	40.00
Change management services	37.84			41.18	41.18	60.00
Reporting services	78.38	82.86	82.86			60.00
Business consulting services	81.08	85.71	85.71	88.24	88.24	100.00

According to the results from TURF analysis, business consulting services, reporting services and change management services, i.e. Line 1, has the highest score of 94.87%. Therefore, services in Line 1 represent candidates to be included in phase II of decision making for final selection and segregation of core from actual and augmented operations services.

4.3.2. ANP-BOCR results for segregation of core from actual and augmented services

In this phase, the authors of the paper have selected eight (8) existing and three (3) new services to be evaluated using ANP-BOCR multi-criteria method. Pair-comparison is carried out by decision maker of the bank under the study to segregate core from actual and augmented operations services. The results are shown in Table 4.

Table 4: Results from ANP-BOCR model

Name	Ideals	Normals	Raw	Segregation
Domestic and international payment transactions services	1.000	0.128	1.000	Core
Reporting services	1.000	0.128	1.000	Core
Business consulting services	0.800	0.103	0.800	Core
Centralized cheques clearing services	0.800	0.103	0.800	Core
Retail and corporate loan services	0.800	0.103	0.800	Core
Premises maintenance	0.800	0.103	0.800	Core
Trade finance services	0.800	0.103	0.800	Core
Business analysis services	0.600	0.077	0.600	Actual
Procurement services	0.600	0.077	0.600	Actual
Change management services	0.400	0.051	0.400	Augmented
Treasury settlement services	0.200	0.026	0.200	Augmented

According to the results, 64% of selected services are categorized as core, followed by 18% of actual services, while 18% of services are recognized as augmented. Besides, of the three new services from Line 1, which were the subject of evaluation, two have been identified as core services of the bank included in this study.

5. CONCLUSION AND RECOMMENDATIONS

This study aims to shed light the understanding of recently advocated paradigms that will substantially reshape operations management in banking industry in years to come, as a result of mainly external forces that are changing the market at high speed, and consequently put pressure on operations managers in banking to continuously change its strategic context and competitive dynamics. The fundamental requirement in the evolution process is change of operating models, which imply an introduction and application of appropriate strategies, paradigms and tools towards economic sustainability of an organization. With that in mind, this paper presents an overview of innovative concepts with holistic perspective, i.e. mass customized-lean-agile-fit paradigms, provides a solution for effective support of mass customized-lean-agile-fit operations strategies, and answers on the question what operations management needs to provide to internal and external stakeholders to meet both strategic goals and end users' requirements.

To answer "how" to effectively support mass customized-lean-agile-fit operations strategies in banking, we have developed a conceptual architecture of digital platform for operations services. A conceptual architecture aims to visualize operations activities, reduce complexity and time to market, while links value chain from front to end, in order to effectively provide mass customized services, information and knowledge. The purpose of this platform is to enable continuous optimization, improvement of operations processes by eliminating waste and by allowing a quick respond to changes in demand in terms of both, volume and diversity. Further, taking into account that the major challenge in mass customization paradigm is to determine product offerings, we propose a two-phase approach consisting of Total Unduplicated Reach and Frequency (TURF) analysis to facilitate a choice of new services imposed by market requirements and Analytic Network Process based on BOCR model (ANP-BOCR) to segregate a core from actual and augmented mass customized services.

To sustain in today's highly dynamic and volatile business environment, based on the reviewed literature and the results obtained from the study, this paper draws some recommendations for managers in financial services: (a) Incorporation of integrated mass customization, lean and agile paradigms into the operations strategies, (b) Development of innovative and flexible solutions with established continuous monitoring and measuring of operations performances, (c) Development of smart processes focused simultaneously on the efficiency and effectiveness of banking operations, (d) Adoption of comprehensive, quantitative, and objective approach to decision-making with the development of a systematic, logical and ambidextrous view on the problem, and (e) The use of appropriate tools and decision support software solutions (Čupić & Suknović, 2010).

The study may be useful for operations managers in financial services, innovation, IT and business decision management.

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APPLICATION OF THE GAMES IN TEACHING LOGISTICS AND SUPPLY CHAIN MANAGEMENT IN THE REPUBLIC OF SERBIA

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Abstract: *This research paper examines the current state of the application of the educational games in teaching logistics and supply chain management (SCM) in higher education institutions in the Republic of Serbia. The data for the study were collected from competent teaching staff through a questionnaire administered on-line using Qualtrics Research Suite. The results of the study show that educational games are not used to a great extent in teaching logistics and SCM at faculties in the Republic of Serbia. The most common reason for this lies in that teaching staff is not sufficiently familiar with the logistics and SCM games. At the same time, the results reveal the ubiquitous interest of the teaching staff for games introduction into the teaching of logistics and SCM. When it comes to the teaching scholars who use educational games, the results show that educational games are equally used at the state and private faculties and that the teachers are satisfied with the possibilities of improving students' competences with the use of games.*

Keywords*: logistics, supply chain management, educational games, application, questionnaire, faculties, Republic of Serbia*

1. INTRODUCTION

The application of educational games in synergy with other teaching methods is one of the perspective ways to enhance teaching and learning in the field of logistics and supply chain management. Most teachers of logistics and supply chain management from several leading institutions of higher education in the US use at least one game, simulation and/or interactive exercise in addition to other teaching methods such as lectures and case studies (according to Johnson and Pyke, 2000). Also, most teachers across the world who teach logistics and SCM would like to use business games/simulations in future (according to study by Rogers and Braziotis, 2016, p. 557). Much of the literature on logistics and SCM games is focused on the development and/or use of specific games; whereby the majority of papers is concerned with the most famous of them – Beer Game and their different versions (e.g. Sterman, 1989; Jacobs, 2000; Ngai et al., 2012; Lau, 2015). However, there is a little empirical evidence on the extent of the use of educational games in teaching logistics and SCM within the higher education institutions. The purpose of this paper is to examine the current state of the application of the educational games in teaching logistics and SCM in higher education institutions in the Republic of Serbia. The study is based on the findings of an on-line questionnaire sent to competent teaching staff working on faculties in Serbia.

2. THEORETICAL BACKGROUND

There are a number of educational games that can be employed in teaching logistics and SCM courses. They simulate the realities of a particular logistics or supply chain management problem, "allowing the students (players) to develop a thorough understanding of the problem and to design and test various solution strategies in an engaging environment" (according to Cambel et al., 2000, p. 68). These games allow students to learn through playing different roles, e.g. an inventory manager, a logistics engineer, a distribution network designer, a supply chain engineer, a supply chain manager, etc., in an environment 'without real risks' that consists of virtual entities (Cvetić et al., 2013, p. 1527). Students can compete individually and as a team memebers, with each other or against the standard, as in other games, and make learning and acquiring experience more interesting. The logistics and SCM educational games are very useful because they can enhance learning experience as they help connect learning theory with real-world dynamic situations; they improve students' active involvement in the learning process; increase students' motivation, and develop specific fundamental and professional competences (Pasin and Giroux, 2011). A brief historical background about these games and several ways of their classification are presented in Cvetić et al., 2013. When it comes to the empirical studies on their usage in teaching logistics and SCM in institutions of higher education, the available literature is almost scarce and slightly wider context should be considered i.e. the usage of business simulation games. Here, only two such studies are indicated. Faria and Wellington (2004) examine the game users, former-users, and never-users of businees simulation games in higher education business schools in the US. Zoroja (2013) investigates the application of business simulation games at the economics departments of higher education institutions in Croatia.

3. METHODOLOGY

The study of the application of the educational games in teaching logistics and SCM at faculties in the Republic of Serbia was conducted during October and November of 2013. The main aim of the study was to determine and understand the level of application of the logistics and SCM games at faculties in the Republic of Serbia. Additionally, other important objectives were to identify the reasons why some teachers do not use these games, to determine the level of interest of teaching staff for games introduction into the teaching process, to determine which games are used in teaching, as well as to reveal the perceived possibility of improvement of students' competences by using the games.

Accordingly, the aim of the study was to test the following hypotheses:

- educational games are not used to a great extent in teaching logistics and SCM at faculties in the Republic of Serbia;
- the teachers that use games in teaching logistics and SCM are satisfied with the possibilities of improving students' competences with the use of the games;
- the teachers are not familiar with the logistics and SCM games; and
- the teachers are interested in the application of games in teaching logistics and SCM.

The study was conducted in the following seven phases:

1. Determination of population of teaching staff in the field of logistics and SCM at faculties in the Republic of Serbia;
2. Identification of risks related to the study and ways of their mitigation and/or overcoming;
3. Creation of Questionnaire on the application of educational games in teaching logistics and SCM at faculties in the Republic of Serbia;
4. Selection of method of sending the questionnaires and collecting the completed questionnaires;
5. Design of Questionnaire by selected tool;
6. Sending the invitations for participation in the survey and collecting the completed questionnaires; and
7. Analysis of results.

In the first phase, the data about the population of teaching staff in the field of logistics and SCM within the accredited study programs at universities and faculties in the Republic of Serbia were collected. In that sense, different documents and data were used, such as: "Guide through accredited study programs in the institutions of higher education in the Republic of Serbia" published by the Serbian Commission for Accreditation and Quality Assurance (CAQA) in 2013, "The list of accredited faculties and universities" published by the Ministry of Education, Science and Technological Development in 2013, the data from the official websites of higher education institutions and the data from direct contact with the representative of one faculty. The total of 16 accredited universities (8 state and 8 private universities), and within them 114 accredited faculties and 5 integrated universities, were considered. After consideration, it was determined that at 26 faculties there are courses in the field of logistics and SCM (15 state and 11 private faculties), with that the total of 70 teaching staff (44 teachers and 26 teaching assistants) are engaged in teaching these courses. Then, the data about teaching staff were collected (the title, the first and last name(s), and the official e-mail address).

In the second phase, the specific risks related to conducting the study were identified and named: distrust of respondents, the disinterest of respondents, the busyness of respondents, and disturbing of respondents (see Table 1). Next, the ways of mitigation and/or overcoming these risks were determined in order to provide a higher response rate.

In the third phase, the Questionnaire on the application of educational games in teaching logistics and SCM at faculties in the Republic of Serbia was created. The attention was given to the aims of the study and hypotheses; to the specific requirements about an appropriate number of relevant, clear, and short questions; to using open-ended response questions and fixed-alternative questions; to grouping questions, etc. The recommendations given in Zikmund et al, 2010, p. 337-352, were very useful during this phase of the study. The final version of Questionnaire was organized into the following five parts: 1. Introduction part; 2. The part called "Teaching in the field of logistics and SCM"; 3. "Educational games in teaching logistics and SCM"; 4. "Application of educational games in teaching logistics and SCM"; and 5. Final part of Questionnaire. At the end, the Questionnaire was technically and professionally checked.

In the fourth phase, the method of sending the questionnaires and collecting the completed questionnaires was chosen. First, it was decided to use an on-line questionnaire and accordingly to electronically collect the filled-in questionnaires. Then, several tools which enable the use of on-line questionnaires were considered, like Google Forms (https://docs.google.com/forms), SurveyMonkey (https://www.surveymonkey.com), SurveyGizmo (http://www.surveygizmo.com), Qualtrics Research Suite (http://www.qualtrics.com), etc. Finally, the Qualtrics Research Suite was selected based on good recommendations from several researchers (Zikmund, et al., 2010; Machado, 2012), price and attractiveness of different options (about 100 types of questions, the user can manage the activation of questionnaire, use of the Serbian language, redirection of questions based on answers, a possibility for respondents to take a break during the process of responding, use of visual indicator about completion of questionnaire, good options for visual design of questionnaire, easy collecting of data).

Table 1: Ways of overcoming risks related to conducting the study

Risks	Ways of overcoming risks
Distrust of respondents	– sending the personalized invitation for participation in the study with a carefully chosen subject of the e-mail – providing the highest possible level of anonymity of respondents
Disinterest of respondents	– providing a prize for respondents – sending the clear and short invitations for participation in the study – pointing out to the time required for completion of the questionnaire – making clear and short questions – using open-ended response questions at the beginning of the questionnaire in order to focus respondents on the questioning process (recommendation adopted from Zikmund et al, 2010, p. 338)
Busyness of respondents	– using on-line questionnaires – providing respondents to complete the questionnaire in a short period of time – providing respondents to take a break during the process of completion of the questionnaire – providing respondents the possibility to see the level of completion of the questionnaire, with a status bar or some other visual indicator of questionnaire length (recommendation adopted from Zikmund et al, 2010, p. 356-357) – making the appropriate number of relevant, clear and short questions – organizing the questions in several groups according to the topics – providing respondents to receive the invitations for participation in the study on Monday morning – limiting the horizontal visibility of questionnaire because of its display on different versions of the web browser – displaying the questionnaire page by page and avoiding that respondent need to scroll through the questionnaire (Zikmund et al, 2010, p. 356-357) – limiting the process of questioning to the previously defined number of days
Disturbing of respondents	– exclusively sending 1 invitation for participation in the survey by e-mail

In the fifth phase, the Questionnaire was designed and tested with the help of the Qualtrics Research Suite. One part of the Questionnaire is given in Figure 1.

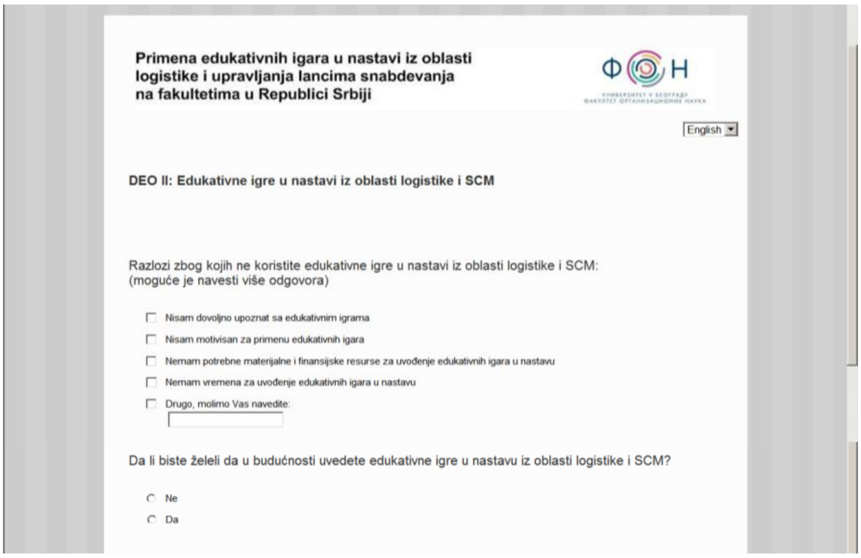

Figure 1: Questionnaire on the application of educational games in teaching logistics and SCM at faculties in the Republic of Serbia **(one part)**

In the sixth phase, the Questionnaire was activated and then the personalized invitations for participation in questioning were sent from the author' personalized e-mail address. The invitations were sent only one time because of the potential disturbance of respondents. During this process, sending of one invitation was unsuccessful, even after multiple attempts. Included in the invitation was a brief explanation of the study and a statement that participants in questioning will get a database of 55 logistics and SCM educational games as a prize. The Questionnaire was active 25 days, and during this time, the completed questionnaires were automatically collected.

In the seventh phase, the analysis of results was done. In doing so, the questions with multiple responses were analyzed by Multiple Response Analysis (MRA), and more precisely with the Multiple-Dichotomy Method because of the type of the used questions. Also, non-parametric statistical tests were used because of a small number of respondents (and consequently – inadequacy to testing the normality of the distributions of the used variables). The analyzes are all done by the help of tools MS Excel and SPSS Statistics 17.0.

4. RESULTS OF STUDY

The population of teaching staff in the field of logistics and SCM at faculties in the Republic of Serbia consisted of 70 teachers and teaching assistants who work within 26 accredited faculties. The invitations for participation in questioning are successfully sent to 69 teachers and teaching assistants. The total of 32 completed questionnaires is collected from teaching staff of 17 different faculties. Therefore, the response rate of teaching staff is 46.38%, and is considered acceptable. It is interesting to mention that the response rate of teachers (51.16%) is higher than the response rate of teaching assistants (38.46%).

More than half of teaching staff that participates in the survey (54.55%) have experience between 3 and 8 years in teaching logistics and SCM courses. About 10% of teachers from state faculties who teach logistics courses for more than 20 years, as well as about 10% of teachers from private faculties who teach in this field less than 3 years were among respondents.

All respondents use traditional teaching methods such as lectures and discussions, as it was expected; and 15.63% of them use only this method. Then, 68.75% of respondents use case studies; 43.75% of respondents use simulations; and exactly half of the respondents (50%) use simulations and/or educational games in combination with other teaching methods. In addition to the offered teaching methods, the respondents mentioned tutorials and mentoring work with students, visits to the Free zone and relevant companies.

Only about one-fifth of the respondents (18.75%) stated that they used educational games, and thus, it can be generally concluded that educational games are not used to a great extent in teaching logistics and SCM at faculties in the Republic of Serbia. The respondents who use games work at 5 different state and private faculties. There was no statistically significant difference between the game users of state and private faculties (Fisher's exact test: *p(2-sided)*=0.063), i.e. games are equally used both at the state and private faculties.

The respondents-non-users of games cited during the questioning several reasons why they do not use educational games in teaching logistics and SCM. These are:

1. lack of familiarity with educational games;
2. lack of required material and financial resources for games introduction into teaching;
3. lack of time for game introduction into teaching;
4. the little interest of students, in the sense that most students are only interested how to "arrive" at the desired grade;
5. lack of motivation for applying educational games;
6. lack of agreement between teachers and teaching assistants in relation to using games, wherein the problem is participation scoring;
7. a view that learning should be a hard and serious job, so there is no need for games introduction; and
8. An insufficient number of teaching assistants.

The four of these reasons were offered, and the other four were identified based on respondents' responses. Respondents gave a total of 41 reasons, which indicates that more than half of the respondents stated more than 1 reason.

The two most common reasons why respondents do not use educational games in teaching logistics and SCM are:

1. lack of familiarity with educational games according to 61.54% of respondents; and
2. lack of required material and financial resources for games introduction into teaching according to 42.31% of respondents.

The reason of lack of familiarity with educational games was given by 57.90% of teachers and 71.43% of teaching assistants (no statistically significant difference was found, Fisher's exact test: *p(2-sided)*=0.668), (see Table 2). This same reason was stated by 65.22% of respondents from state faculties and 33.33% of respondents from private faculties (also, no statistically significant difference was found, Fisher's exact test: *p(2-sided)*=0.538).

The reason of lack of required material and financial resources for games introduction into teaching was stated by 47.37% of teachers and 28.57% teaching assistants (no statistically significant difference was found, Fisher's exact test: *p(2-sided)*=0.658). Also, this reason was stated by 43.48% respondents from state faculties and 33.33% respondents from private faculties (no statistically significant difference was found, Fisher's exact test: *p(2-sided)*=1.000), see Table 2.

Table 2: The two most common reasons why respondents do not use games

	The two most common reasons why respondents do not use educational games in teaching logistics and SCM at faculties in the Republic of Serbia (*N*=26)		
	N	Lack of familiarity with educational games	Lack of required material and financial resources
Teaching staff			
Teachers	19	11	9
Teaching assistants	7	5	2
Fisher's exact test		0.668	0.658
Faculties			
State faculties	23	15	10
Private faculties	3	1	1
Fisher's exact test		0.538	1.000

*significant for $p<0.05$; **significant for $p<0.01$

It is interesting that all respondents who do not use educational games in teaching logistics and SCM stated that they would like to introduce educational games in teaching in this field in future, except one respondent who did not want to answer this question.

A small number of respondents uses games in teaching logistics and SCM at faculties in the Republic of Serbia (*N*=6), as we previously concluded. They use 2 games in average (*N*=6; mean *M*=2.33; standard deviation *SD*=1.21). From the answers, it can be seen that both manual and computer versions of games are in use; mostly free games, but also games that cost more than 450 Euros; most games are already developed by others, as well as new games developed according to their own needs. All respondents-users of games in teaching indicated that the games positively influence on the interest in courses. Furthermore, these respondents were asked to rate how much it is easy or difficult to improve certain fundamental competences of students by using games on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). In that sense, they evaluated the following competences: solving problems, decision making, planning and organizing of tasks, communication, and team-work. The selected results are presented in the form of radar chart in Figure 2. These results show that the observed teachers are satisfied with the possibilities of improving students' competences with the use of games.

A half of respondents (*N*=16) gave additional comments on the application of games in teaching logistics and SCM. Their comments are divided into three groups:

- positive comments – that point out the advantages of using games in teaching;
- constructive comments – that give useful suggestions in relation to the use of games in teaching; and
- comments of non-supporters of the games – that observe the use of games as unnecessary and/or useless activity.

Thus, ten comments are classified in the group of positive comments (62.50%), five in the group of constructive comments (31.25%), and one in the group of comments of non-supporters of the games (6.25%).

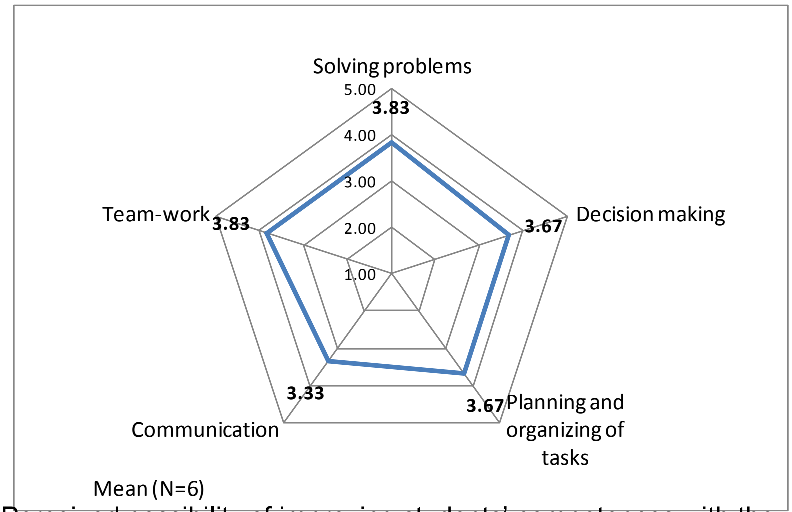

Figure 2: Perceived possibility of improving students' competences with the use of games

Finally, 84.38% of participants were interested in getting a database of 55 logistics and SCM games.

5. DISCUSSION OF RESULTS

In this study on the application of the logistics and SCM games, 46.38% of competent teaching staff from the higher education institutions in the Republic of Serbia participated. The obtained response rate is considered acceptable based on specifics of populations, which can be justified by considerations and data given in Neuman (1997), Chang (2003), Faria and Wellington (2004), Lean et al. (2006), and Zoroja (2013). Thus, according to Neuman (1997), p. 247, the adequate response rate presents the assessment which depends on population, practical limitations, topics and answers with which researchers feel comfortable so that the response rates less than 50% can be accepted. Moreover, in some of the previous studies on using simulations and/or games in teaching (such as Chang, 2003; Faria and Wellington, 2004; Lean et al., 2006; and Zoroja, 2013), the adequate response rates were less than 25%. Hence, it can be generally concluded that the teaching staff is a specific population not much interested in participating in studies of this type.

The results of this study confirm that educational games are not used to a great extent in teaching logistics and SCM at faculties in the Republic of Serbia. Only around one-fifth of the respondents (18.75%) actually use games in teaching in this field. Additionally, an interesting fact is that exactly half of the respondents (50%) use simulations and/or educational games in combination with other teaching methods. This data is very different from the conclusion expressed in Johnson and Pyke (2000) – that most teachers use at least one game, simulation and/or interactive exercise in addition to other teaching methods for teaching logistics and SCM. However, this conclusion was derived based on analysis of courses from the several leading institutions of higher education in the US. On the other hand, if the data was considered from the wider context i.e. compared to users of business simulation games (studies like Faria and Wellington, 2004; Zoroja, 2013), they could be positively interpreted. Thus, according to Faria and Wellington (2004), 30.6% of teaching staff from the higher education business schools in the US use business simulation games (study conducted in 2003). The study from Croatia conducted in 2012 shows that 26.32% of teaching staff from the business and economics departments of higher education institutions in this country are users of business simulation games (Zoroja, 2013).

The results show that the teachers who use games in teaching are satisfied with the possibilities of improving students' competences with the use of games. Here, it should be acknowledged that this conclusion is derived based on a small number of respondents who use games. The aforementioned reason also limits the consideration of using manual vs. computer versions of games, free games vs. commercial games, and similar comparisons.

The results of the study confirm that teaching staff is not sufficiently familiar with the logistics and SCM games. This reason was stated by more than half of respondents (61.54%). Of course, this can be closely connected with the small number of respondents-users of games, as Faria and Wellington (2004), p. 198, pointed out that it is difficult to be a game user if one is not familiar with games. The other reasons of non-users of games were: a lack of required material and financial resources for games introduction into teaching, a lack of time for game introduction into teaching, a perceived little interest of students, etc. We believe that the identification and understanding of these reasons are important for future activities in the sense of their mitigation/overcoming. At the same time, the findings show the ubiquitous interest of the teaching staff for games introduction into the teaching of logistics and SCM at faculties in the Republic of Serbia. The analysis of comments confirms that teaching staff has positive attitudes to the use of games in the teaching process.

While the data for this study is derived from a population-based questioning, it is important to note obvious limitations to the generalizability of the findings. The population of teaching staff from the field of logistics and SCM in the Republic of Serbia was small. Additionally, the response rate to the questionnaire was 46.38% and the group of respondents-users of logistics and SCM games were under-represented.

6. CONCLUSION

This is one of the first empirical studies of the application of educational games in teaching logistics and supply chain management which has been conducted in the Republic of Serbia. The study answers the following questions: "What is the level of application of the logistics and SCM games at faculties in the Republic of Serbia?", "Are the teaching staff satisfied with the effects of using the games?", "What are the reasons for not using the games in teaching?", "Is the teaching staff interested in introducing games in teaching logistics and SCM?", and some other issues that are not covered in this paper. One of the main findings of this study that there is a large number of teaching scholars who not use logistics and SCM games in the Republic of Serbia, probably most of all due to a lack of familiarity with these games and of course the other reasons, is not surprising. This suggests a need for further investigation of the effectiveness of using games in logistics and SCM courses. We believe that more empirical studies about the effects of employing games in addition to the other teaching methods could stimulate an interest in games amongst teaching staff currently not familiar with them. Additionally, the development of methods of the selection of games and tools like DST SLSCMG (Decision Support Tool for the Selection of Logistics and Supply Chain Management Games) (see Cvetić et al., 2013), then development and application of a new frameworks or models of learning logistics and SCM based on games (such as those presented in Lewis and Maylor, 2007; Huang et al., 2008), can be useful to current and potential logistics and SCM game users.

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